INSTRUCTIONS TO YOUNG ZOOLOGISTS

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by

C. L. DUDDINGTON
M.A., Ph.D., F.L.S.
AUTHOR OF "INSTRUCTIONS TO YOUNG BOTANISTS"

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To
John and Anne Webster
whose father helped me a lot
in writing this book

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CHAPTER I

INTRODUCTION

This book is about the Animal Kingdom, and the many different kinds of animals that inhabit the earth. The number of different animals that we know is so huge—there are more than 800,000 different insects alone—that I cannot hope to do more than give you an outline. At the back of the book, however, you will find a list of books that will help you to extend your knowledge of animals if you wish to do so. I hope that you will.

The study of living things is called Biology—from the Greek word *bios*, meaning life. The study of animals is known as Zoölogy—pronounced *zo*-ology and not *zoo*-ology—while that of plants is Botany. Zoology is a very large science, for not only are there very many animals, but they can be studied in so many different ways. We can, for instance, chop them up—dissect them, to be more precise—and study the way in which their bodies are built up. This is Anatomy. Alternatively we can investigate the way in which their bodies work: how they digest their food, how they breathe, what their various organs do: in other words, "what makes them tick." This is Physiology. We may prefer to examine the various complicated ways in which animals are related to the world in which they live—what lives where, with whom, and why. This particularly interesting branch of the subject is called Ecology. We can also study the development of an animal from the egg (Embryology), or how it resembles and differs from its parents, and why (Genetics). So you can see that Zoology covers a very wide field.

The province of the biologist, whether he is a botanist or a zoologist, is the study of living organisms (any living thing can be called an organism, whether it is an animal or a plant). Living things differ from non-living matter in a number of definite ways,

and, although the boundary between living and non-living is not always easy to define, it is usually easy enough to decide whether a given object is alive or not.

To begin with, most living things have the power of movement. This is true even of plants, for we have all seen a potted plant growing in a room bending its stem towards the window, or a runner bean plant twining itself round its supporting stake. Even an animal like a barnacle or a sea anemone shows movement at some time or other.

Living organisms also show certain universal chemical activities. They all take in food and incorporate it into their bodies, they all produce waste products which they must dispose of (excretion), and they all show the phenomenon of respiration, in which chemical energy is released and used by the organism to enable it to move, and to keep its vital processes going. The energy produced by respiration comes from the food.

Two other processes are universal in living organisms. One is irritability. By this I do not mean that all living things are bad-tempered, however true this may be of some. I mean that they are sensitive to such things as heat, cold, touch, contact with chemicals and so on, and able to react in an appropriate way when any of these things comes into contact with them. If you put your hand accidentally on something very hot, you immediately withdraw it. That is irritability.

The other universal property of living organisms is the power of reproduction—the ability to produce young resembling themselves. Without this, life would soon come to an end, for there would be nothing to replace the organisms that must eventually die.

These, then, are the characteristics by which we may recognize a living organism, and they apply both to animals and plants.

It is not always easy to distinguish between an animal and a plant. This may seem strange, and of course it is true that, in most cases, there is no difficulty at all. It is quite obvious that a cat is an animal, and nobody would deny that a tree is a plant. There are, however, instances where the decision is not so easy.

In the next chapter I shall be telling you something about a little creature called *Euglena*. It is a microscopic organism found in water, where it swims about actively by means of a waving "tail" or flagellum. In this it appears to be an animal. On the

other hand, *Euglena* is green: it possesses the green pigment, chlorophyll, that is characteristic of plants. What then are we to call it? Animal or plant?

Consider also the sea anemone. This spends most of its life attached to a rock—yet it is without doubt an animal.

The best way to decide whether an organism is a plant or an animal is to see how it feeds. Plants have chlorophyll—that is why they are green. This makes it possible for them to absorb carbon dioxide gas from the air and, with the aid of sunlight, to make sugar from it. In this way, they can get all the organic matter they need to nourish them. Given carbon dioxide, water, sunlight and a few mineral salts from the soil, a green plant can manufacture its own food. Not so an animal. An animal must have organic food, that is, food derived from material that was once living, either animal or plant. Lacking chlorophyll, it cannot build up organic compounds for itself.

Unfortunately, this way of distinguishing between animals and plants is not infallible. Fungi, such as mushrooms and toadstools, are plants without chlorophyll: they have to take in organic food as animals do, and this they get from the organic matter (humus) in the soil. In *Euglena* we have an organism that moves like an animal, yet feeds like a plant. In these borderline cases the general rule breaks down.

There is one important property that is shared by animals and plants: their bodies are made up of units called cells. These are the bricks, as it were, out of which living things are built, and we cannot understand the structure of an organism, or how it lives, without knowing something about the nature of cells.

A living cell (Fig. 1) is made up of a jelly-like substance called protoplasm. This was aptly called by Huxley "the physical basis of life": it is the substance out of which living organisms are made, and the various phenomena that we associate with living things, such as respiration, irritability and the like, are in fact properties of living protoplasm.

I have called protoplasm "jelly-like." This is, in fact, much too simple a way of putting it. Protoplasm has some of the properties of a liquid, and some of the properties of a jelly, and it can change from jelly to liquid and from liquid to jelly again with great ease. Chemically, it is enormously complicated, and its composition and properties are continually

changing—for the ability to change is one of the most important properties of living things. How it is that protoplasm is liable to exhibit the wonderful and mysterious phenomena that are connected with what we call life, we do not know. This is a mystery

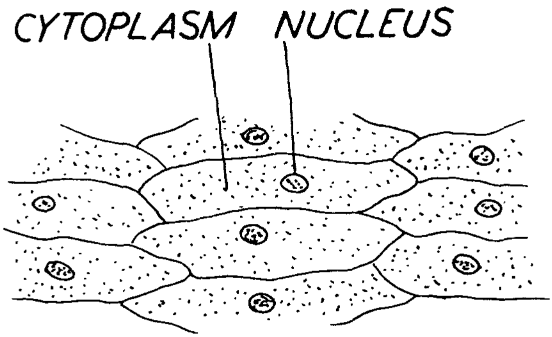


Fig. 1. Portion of animal tissue, as seen through a microscope, showing cellular structure.

that the biologist is no nearer penetrating now than he was when biology first started.

The protoplasm of a living cell nearly always contains a small, dense body called the nucleus. Sometimes a cell may have more than one. The nucleus is itself composed of protoplasm, and it is a very important part of the cell, for it appears to control its activities. If the nucleus is removed from a cell, the cell dies. The nucleus has another important function : it carries the genes—the mysterious things that decide the hereditary characteristics of the organism. If you happen to have red hair or blue eyes, it is because the genes in the nuclei of your cells have decided it.

A living cell is always surrounded by a cell membrane. This may be simply a special outer layer of the protoplasm itself, or it may be something thicker—a kind of skin, enclosing the cell like the skin of a sausage. In plants the cells are usually enclosed in a box-like cell wall, often rather like a honeycomb, made of a substance called cellulose, but animal cells do not usually have rigid walls of this kind.

Many cells contain, within their protoplasm, spaces filled usually with liquid, though sometimes with gas. These are called vacuoles. Various other things may also be found in cells, and these cell-inclusions, as they are called, may be part of the living

protoplasm, or they may be dead material that the cell has accumulated for one reason or another.

Cells are usually very small indeed. There are exceptions to this: an ostrich egg, for instance, is a single cell, puffed out, as it were, with food (yolk) for the developing chick. Usually, however, cells are so small that they cannot be seen without a microscope. The number of cells that go to make up the body of quite a moderate-sized animal is, therefore, so large that only an astronomer can handle it comfortably.

The number of different animals that we know is very large indeed, and they all must have names. To find "popular" names for such a vast array would be quite impossible, and so they are given Latin names instead. This has the further advantage that the names will come the same to zoologists of all nationalities. It would obviously be unfair to insist that the names of all animals should be in English or French or Chinese or any other living language. Every animal has two Latin names: the first is called the genus and the second the species. The genus can be compared with the surname, and the species with the Christian name, the surname being put first, as in a telephone directory. Thus, the domestic cat is *Felis domestica*, the tiger is *Felis tigris*, the rabbit is *Oryctolagus cuniculus*, and so on. The fact that both cat and tiger have the same genus name (*Felis*) while the rabbit has a different one (*Oryctolagus*) indicates that we think the cat and the tiger are more closely related to one another than either is to the rabbit. We always try to classify animals so that relationships between them are brought out—just as two brothers will have the same surname, while their cousin may have a different one, and the surname of a perfect stranger will almost certainly be different.

To bring out relationships still further, animals that are related to one another are grouped together. Thus all the cat tribe—cat, tiger, jaguar, leopard and so on—belong to the Felidae, while the dog, wolf, fox, etc., belong to the Canidae. Both the Felidae and the Canidae are members of a yet larger group, the Carnivora or flesh-eaters, and so on, the groups getting larger and larger as we bring more and more smaller groups together. The biggest groups of all are called Phyla.

One more thing before we begin on our survey of the Animal Kingdom. You cannot really learn about animals just by reading

books and looking at pictures. You need to go out as much as possible to look at the animals themselves. Study them in the field, go to the zoo whenever you can (you may have one in your neighbourhood), and don't forget your local museum—there are bound to be specimens there. You can also learn a lot from your own pets. Zoology should be a *living* study—not something you learn from books.

CHAPTER II

THE SIMPLEST ANIMALS—PHYLUM PROTOZOA

In the last chapter I said that the bodies of animals are built up of large numbers of cells, as a house is built of bricks. There is, however, one great group of animals to which this does not apply. These are the Protozoa—very small, and often very simple, animals whose bodies consist of one cell only.

The Protozoa are very small indeed, and to study them a microscope is needed, though some of the larger ones are just visible to the naked eye. They are called Protozoa because we believe that these were the first animals to appear upon the earth, more than a thousand million years ago, before most of the rocks that are familiar to us today had even been formed.

One of the simplest of all the Protozoa is *Amoeba*. There are many species, found in water, in the soil and in other places. *A. proteus* is a large species that lives in the mud of ponds, though it is not very common; it is usually about a hundredth of an inch in diameter, and so can just be seen with the naked eye as a tiny speck. Many amoebae, especially those found in soil, are much smaller than this.

If we look at *Amoeba* through a microscope, we see an irregularly shaped blob of jelly-like protoplasm. Somewhere within the animal is a denser part, the nucleus. This is difficult to see while the animal is alive, but if we kill the *Amoeba* and stain it with a suitable dye, the nucleus stands out clearly. There is also a round, clear area that, in a living animal, gets gradually larger as we look at it, until it suddenly disappears and starts to form again. This is the contractile vacuole. It is a space filled with water, and it is the means by which the *Amoeba* pumps out water that it does not need (Fig. 2).

The protoplasm of *Amoeba* forms two layers. The outer layer,

called the ectoplasm, is clear and transparent, and it is jelly-like and fairly firm. It encloses the inner layer, or endoplasm, which is more fluid. The endoplasm is less transparent than the ectoplasm, for it contains many small granules. It also contains

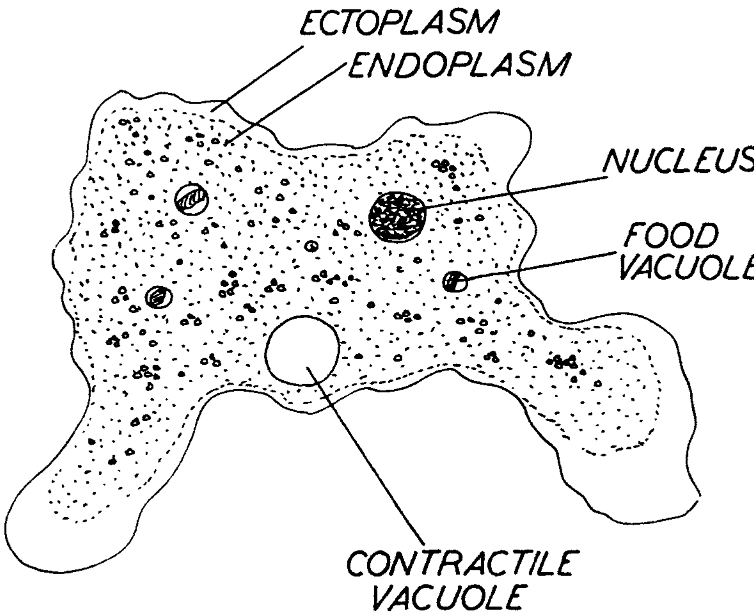


FIG. 2. *Amoeba*, VERY MUCH MAGNIFIED.

numerous larger objects, which are the small organisms on which *Amoeba* feeds, in a state of partial digestion. Each tiny particle of food is surrounded with a droplet of fluid, the food vacuole.

A living *Amoeba* is constantly changing its shape. Its outline is irregular, for it continually puts out blunt extensions of its protoplasm, called pseudopodia, and these may be formed at any point on its surface.

It is not true, however, to say that an *Amoeba* has no shape, for, although its shape is very variable, each species is different and can be recognized by an expert.

An *Amoeba* moves about by means of its pseudopodia. When a pseudopodium is first formed it consists of ectoplasm only, but

as it enlarges the endoplasm runs into it. As the pseudopodium increases in size, the whole animal flows into it, after which another pseudopodium begins to form, and so on. The *Amoeba* moves itself in this way when it is on a solid surface, such as pond mud; if it is floating freely in water its pseudopodia cannot move it.

Amoeba feeds on other organisms, smaller even than itself. When it touches something edible, a pseudopodium is put out on each side of the food particle, so that it is engulfed, together with a droplet of water that forms the food vacuole. The food is then digested by digestive juices that are secreted into the food vacuole (the production of substances, such as digestive juices, by cells is called secretion, and this is a very important duty of certain kinds of cells, called glands, in the animal body). While digestion is going on, the fluid in the food vacuole is acid, just as the contents of our stomachs are acid. When digestion is complete, the indigestible remains of the food are left behind as the animal flows away.

Small though it is, an *Amoeba* shows all the essential characteristics that we associate with living things. It moves, as we have seen; it feeds; it takes in oxygen dissolved in the water in which it lives, for respiration, and gives out carbon dioxide. This exchange of gases takes place, as far as we know, all over its surface. It also gets rid of unwanted waste products (excretion) from the whole of its surface. Although it consists of only one cell, it is self sufficient.

The reproduction of *Amoeba* is as simple as the rest of its life. When it is about to reproduce, the nucleus divides into two, and then the cell itself separates into two portions, one of the newly formed nuclei going to each half. The halves then separate, each becoming a young *Amoeba*, which feeds and grows to full size before it, in turn, divides into two.

This process of reproduction by dividing into two is called fission. In the ordinary way, an *Amoeba* does not die of old age.

Sometimes an *Amoeba* reproduces in a different way. It withdraws its pseudopodia, becoming more or less rounded, and then surrounds itself with a thick covering called a cyst. The nucleus then divides, and the "daughter nuclei" divide again, the process being repeated until there are many nuclei. Small portions of

protoplasm are gathered round each of these nuclei, and then, the cyst wall breaking down, these separate portions, each with its own nucleus, are set free as tiny amoebae with rather pointed pseudopodia. These are called spores, and each of them will, in time, grow into a full-sized *Amoeba*. This process is called multiple fission.

A serious danger that an amoeba has to face is the possibility that the place where it is living may dry up, for obviously an *Amoeba* cannot carry on its normal life under dry conditions. It can escape this danger by forming a cyst, inside which the living protoplasm can exist in a state of "suspended animation," rather like a dormant seed. On the return of moist conditions, the *Amoeba* emerges again from its protective cyst and resumes normal life.

Amoeba is a very simple animal indeed—it could hardly be simpler. A zoologist would call it a very primitive animal, by which he would mean that it is related to very early forms of life. We believe that all forms of animal life—and plant life too—that are alive today have descended from ancestors that were very simple, and which probably consisted, like *Amoeba*, of one cell only.

As time went on, living things got more and more complicated. One-celled animals gave rise to many-celled animals, and from these developed the host of animals without backbones that we call invertebrates. Then animals with backbones appeared—fishes, reptiles, and finally the birds and mammals. Last to appear was man himself.

This gradual process of change is called evolution, and it has taken a very long time—at least a thousand million years. As far as we know, it is still going on.

You will sometimes hear it said that *Amoeba* is the original ancestor of all life. This is almost certainly not true, for we have good reason to believe that some of the Flagellata—tiny Protozoa that swim by means of waving "tails" called flagella—are even more primitive than *Amoeba*.

Let us now have a look at some of these.

If you look through a microscope at some water in which organic matter is decaying, you will almost certainly see several different kinds of one-celled organisms, some of which will probably be moving about actively. Among these it is likely that there

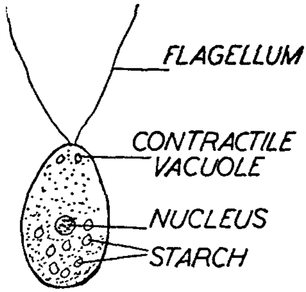


FIG. 3. *Polytoma*, A SMALL ONE-CELLED ANIMAL.

will be a tiny creature called *Polytoma uvella.* It belongs to the Flagellata.

Polytoma consists of a tiny egg-shaped cell (Fig. 3). At the pointed end are a pair of whip-like "tails" called flagella which, by their waving, enable *Polytoma* to swim. The movement of the flagella is rather like the movement of your arms when swimming breast stroke. Also at the pointed end of the cell are a pair of contractile vacuoles, which expand and contract alternately with one another.

There is also, at one side of the animal, a tiny spot of red, called the eye spot. Near the middle of the cell is a nucleus, and the cell often contains a number of starch grains; these serve as a reserve of food.

The fact that *Polytoma* may produce starch gives us a clue to

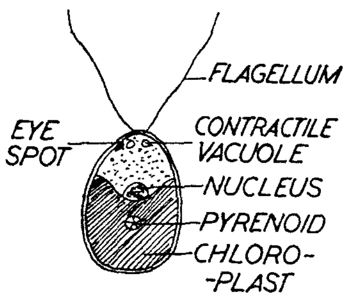


FIG. 4. *Chlamydomonas*, A ONE-CELLED PLANT.

its relationships with other organisms, for starch is a food material that we usually associate with green plants, and not with animals. This suggests that *Polytoma* may be in some way related to plant-like organisms, and there can be no doubt that this is so.

There is a little organism called *Chlamydomonas*, often found in fresh water, that resembles *Polytoma* very closely. *Chlamydomonas* has, however, one structure that *Polytoma* is without. The hinder end of its cell is occupied by a large, cup-shaped, green object, called the chloroplast (Fig. 4). This contains chlorophyll, and with its help *Chlamydomonas* is able to make for itself sugar and starch from carbon dioxide, just as plants do. *Chlamydomonas* is one of those organisms that, like *Euglena* (Chapter I), is on the borderline between the Plant and Animal Kingdoms. You will find it described as a plant in books on Botany, and as an animal in books on Zoology.

We can hardly doubt that *Chlamydomonas* and *Polytoma* are closely related to one another: *Polytoma* is, in fact, a colourless *Chlamydomonas*. Under certain conditions, as when *Chlamydomonas* undergoes multiple fission (page 18) too quickly for the chloroplast to be divided between all the new cells that are formed, some of these new cells are colourless. Such cells cannot be distinguished from *Polytoma*.

We now see why *Polytoma* forms starch as its reserve food. It is a habit that it has kept from its plant-like ancestry. Zoology is full of clues like this, that help us to make out how one animal is related to another.

It is the job of a good zoologist to try to work out these clues correctly, like a detective, and not to be led astray by the false trails that Nature, the criminal in the case, seems to delight in laying for him.

In Chapter I, I mentioned an organism called *Euglena*, which, like *Chlamydomonas*, is a "borderline case" between plant and animal. *Euglena* is found very often in puddles, where it may be so plentiful that the water looks green.

Euglena is a small organism, not more than one hundred-and-fiftieth of an inch long, and shaped like a spindle (Fig. 5). Its hinder end is pointed, but in front it is blunt. At the front end is a scooped-out pit, called the gullet, and from the bottom of this arises a single long, whip-like flagellum, by means of which the tiny creature can swim.

Near the centre of the cell is the nucleus, and arranged round it are a number of oblong chloroplasts containing green chlorophyll. *Euglena* is therefore able to feed like a plant from carbon dioxide dissolved in the water in which it lives. *Euglena* does not manufacture starch, but it does make a rather similar substance

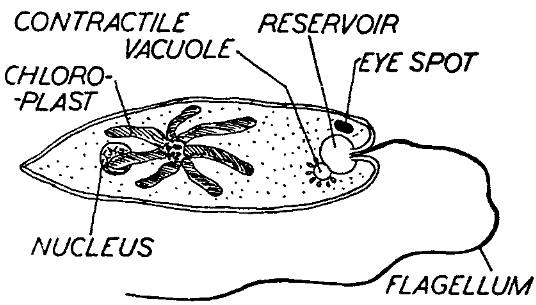


FIG. 5. *Euglena viridis*, A MICROSCOPIC "PLANT-ANIMAL".

called paramylum, granules of which may often be seen at the point where the ends of the oblong chloroplasts meet. It is very unlikely that the so-called gullet of *Euglena* is actually used for taking in food.

At the front end of the cell is a contractile vacuole, which empties into a space called the reservoir, at the base of the gullet.

At the side of the reservoir is a red eye spot, which is sensitive to light. *Euglena* swims towards moderate light and away from very bright light; a sensible habit, for, while it needs some light for the manufacture of food by photosynthesis, too strong a light is harmful to chlorophyll.

We know that *Euglena gracilis* is able to feed in exactly the same way as a plant, and is independent of organic food in the water. Whether this is true of other species, such as the common *E. viridis*, is uncertain.

Euglena reproduces by means of binary fission, in much the same way as *Amoeba*. When the cell divides, the split begins at the front end and travels backwards.

Some of the Flagellata are important because they cause disease in man or animals. One of these is *Trypanosoma gambiense*, which causes sleeping sickness, a terrible scourge in

Central Africa. *T. gambiense* is very small—much smaller even than *Polytoma* or *Chlamydomonas.* It is long and slender, and pointed at both ends, and it has a flagellum that runs along its body, connected with it by a thin sheet of protoplasm called the undulating membrane (Fig. 6).

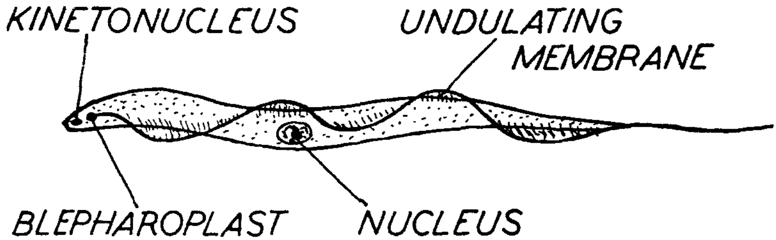


FIG. 6. *Trypanosoma gambiense*, THE ORGANISM CAUSING SLEEPING SICKNESS.

Sleeping sickness is passed on to man by the bite of a fly, rather like one of our horse-flies, called the tsetse fly (pronounced "tetsy"). Its scientific name is *Glossina palpalis.* The fly is a blood-sucker, and when it sucks the blood of a person suffering from sleeping sickness it sucks in some of the trypanosomes. The insect becomes infected, and it can pass on the infection to the next person whose blood it sucks. It is in this way that the disease is spread.

Trypanosoma is an example of a parasite—an organism that lives in or on the body of another creature, feeding from it, and giving nothing in return. Some parasites are comparatively harmless; fleas, for instance, do little injury to their hosts, except when they happen to be the agents by which diseases are spread, as is the case with the oriental rat flea (*Xenopsylla cheopsis*), which passes on to man the germs of bubonic plague—the Black Death of the Middle Ages. Other parasites, like *Trypanosoma gambiense*, may be deadly.

There is one great group of the Protozoa that consists entirely of parasites. These are the Sporozoa, and one of the most important is *Plasmodium*, the organism that causes malaria.

There are several kinds of malaria, caused by different species of *Plasmodium.* The parasite attacks the red blood corpuscles—little round cells that carry the red colouring matter (haemoglobin) that is an essential part of the blood. As a result of the activities of the parasite in the blood, a high fever is produced.

The disease is spread by certain mosquitoes of the genus *Anopheles*.

When the mosquito sucks the blood of a malaria victim, the parasites pass into its stomach, and from there they find their way to the salivary glands round the mouth of the mosquito. When a female mosquito sucks blood—the males feed only on plant juices—she injects a drop of saliva as she punctures the skin of her victims, which prevents the blood from clotting. In doing so, she injects with it the malarial parasite, as surely as if she were using a hypodermic syringe.

The malarial parasite, when injected by the mosquito, does not immediately set up a fever. For about ten days the parasites inhabit the liver, where they are carried by the circulation of the blood, and only after they have lived and multiplied there for a while do they return to the blood and produce the symptoms of malaria.

A form of malaria used to be common in the fen districts of eastern England, before the fens were drained, where it was known as "ague."

Since malaria can be passed on to man only by the bite of a mosquito, our best weapon in combating malaria is the destruction of mosquitoes. This is best done either by draining the swamps where they breed, or by pouring a layer of oil over the surface of the water, so that the pupae of mosquitoes, which hang from the surface of the water, cannot breathe. Nowadays, insecticides such as DDT are extensively used in the fight against malaria. At the beginning of this century, West Africa was known as the "white man's grave," on account of the ravages of malaria; now, thanks largely to mosquito control, it is quite healthy.

The fourth great group of the Protozoa is called the Ciliophora. These are rather more complicated in their structure than the Protozoa that I have so far described, though they still consist each of a single cell.

A very common member of the Ciliophora is *Paramecium*, often called the slipper animalcule because of its fancied resemblance to a slipper. It is found in water containing decaying plant material, and you can often cultivate it by boiling hay in water and just leaving the infusion, as it is called, uncovered for a few days.

From their abundance in infusions of this kind, the Ciliophora were formerly known as the Infusoria.

Paramecium is large for a protozoan: it is just visible to the naked eye as a tiny oblong speck. It is pointed at one end (Fig. 7)

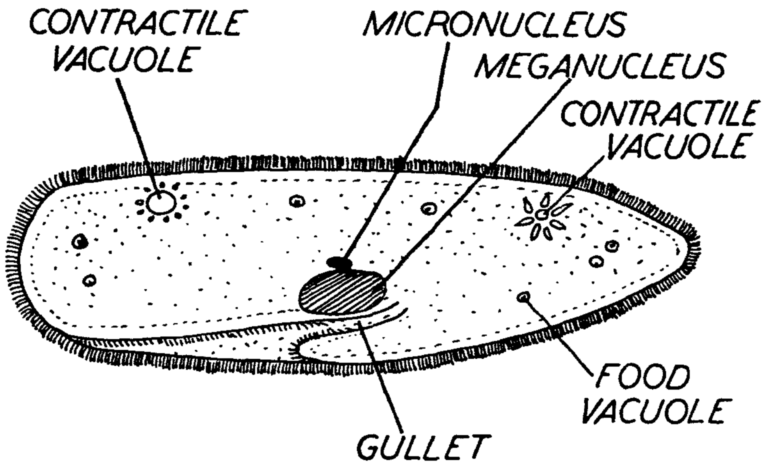


FIG. 7. *Paramecium*, THE "SLIPPER ANIMALCULE."

and slightly flattened, and along one side of the body, which is somewhat twisted, is a deep groove called the peristome. From the groove, a funnel-shaped cavity runs into the cell; this is the gullet, and, unlike the gullet of *Euglena*, it is used for feeding. There are two contractile vacuoles, on the opposite side of the cell to the gullet, and there are also two nuclei, one of which is much larger than the other.

The whole body of *Paramecium* is covered with large numbers of tiny, waving protoplasmic hairs which, by their lashing movement, enable the animal to swim. These are very much smaller than flagella, and are called cilia.

Paramecium, like *Amoeba*, shows a division of its protoplasm into an outer, firm ectoplasm and a softer, granular endoplasm. The outer part of the ectoplasm forms a delicate "skin" or pellicle that covers the animal. Embedded in the ectoplasm are many spindle-shaped objects called trichocysts; these have pointed ends,

and are arranged so that they stand perpendicular to the surface of the animal, pointed ends outwards.

If a *Paramecium* is touched, or if it comes into contact with some substance that irritates it, some of the trichocysts shoot out quickly, becoming much longer. The tip of the trichocyst is sticky, and we think that the trichocysts serve as anchors by which the animal can attach itself to some other object.

Paramecium feeds on other organisms smaller than itself. These are passed into the peristome, propelled by water currents set up by the waving of the cilia that line it, and are taken into the cell through the gullet. The method of feeding thus resembles that of *Amoeba*, excepting that the food is always taken in at the same place. As in *Amoeba*, a droplet of water, taken in with the food, forms a food vacuole in which the food is digested. The food vacuoles, with their contents, circulate round the body in a "figure of eight" before the undigested remains are expelled at a point just behind the gullet.

Small and primitive though it is, *Paramecium* shows some power of distinguishing between particles that are good to eat and grains of material that are not. If it is fed with such things as particles of an insoluble dye it learns to avoid them, and may even "remember" to do so for as long as three days.

Paramecium reproduces by binary fission, the cell splitting across into two halves. It also undergoes a curious process called conjugation—found in many of the Ciliophora—in which two individuals become attached to one another, with their lower sides touching, and exchange nuclear material after a complicated series of divisions of their smaller nuclei. After conjugation they separate again and resume normal life.

Conjugation appears to have an invigorating effect. If it does not take place from time to time, the organisms suffer from a condition known as depression, in which their bodies become distorted and they finally die.

Some of the Ciliophora, instead of swimming freely, remain rooted to one spot for most of their lives. *Vorticella*, often known as the bell animalcule because of its bell-like shape, does this (Fig. 8). *Vorticella* is found in pond water, living attached to water plants, etc. It is shaped like a bell, with a long stalk by which it is fastened to the object on which it is growing.

The bell is solid, and running round its wide end is a groove,

the peristome, corresponding with the peristome of *Paramecium.* The gullet arises from the peristome. In *Vorticella* the cilia are found only at the wide end of the cell, where they form two rows around the edge and down into the vestibule that leads to the

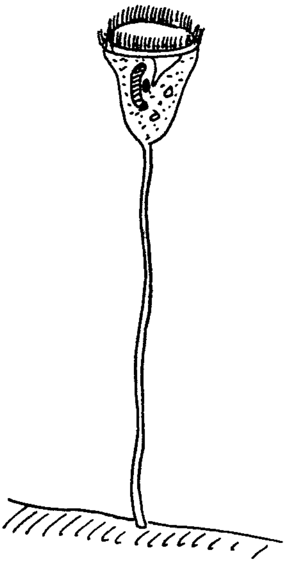


FIG. 8. *Vorticella,* THE "BELL-ANIMALCULE."

gullet. The motion of the cilia sets up water currents that carry food particles—bacteria and other small creatures—towards the gullet, where they are taken in.

Like *Paramecium, Vorticella* has two nuclei, one large and one small. It reproduces by binary fission.

The stalk of *Vorticella* is able to contract, rolling itself into a spiral as it does so. If the bell is touched, it can thus draw back out of the way.

I have called the Protozoa one-celled animals, but this is not altogether a satisfactory way of looking at them. We have seen that in *Paramecium* and *Vorticella* this one cell can become very complex, and these two are simple compared with some of the Ciliophora. It might perhaps be better to regard them as being non-cellular, meaning that we cannot compare them with the

cells that are found in other animals, because of their great complexity.

The Animal Kingdom is commonly divided into three great sub-kingdoms. The Protozoa form one of these; the other two are the Parazoa, including only the sponges, and the Metazoa, in which are placed all the other animals.

CHAPTER III

THE SPONGES—PHYLUM PORIFERA

PEOPLE do not always realize that sponges are animals, but this is so. A bath sponge is really the horny skeleton of a marine animal, *Euspongia officinalis*, found in the Mediterranean and in the seas off the West Indies and Australia. The best bath sponges of commerce come from the Adriatic.

The sponges are sessile animals—that is, they remain stuck in one place instead of moving about as do most other animals. They are complex when compared with such simple creatures as *Amoeba*, for their bodies are built up of many thousands of cells. In spite of this, however, they show clear signs of being related to the Flagellata—the Protozoa with flagella—more closely than to any other group.

There are some peculiar flagellates, called the Choanoflagellata, that may well be the ancestors of the sponges. These are flagellates with a single flagellum, the base of which is surrounded by a curious collar, made of protoplasm (Fig. 9). The Choanoflagellata, like the sponges, are usually sessile: they are fixed in one place by a stalk attached to the end of the cell opposite to the flagellum. Many of them form colonies, a number of cells being joined by their stalks.

We can make out the structure of a sponge if we look first at a little creature called an olynthus. This is a young stage through which many sponges pass before they reach their adult form; it shows the main characters that are common to sponges, but is simpler than any known fully grown sponge.

An olynthus is shaped rather like a vase, with a slender stem and an opening at the top (Fig. 10). It is hollow, and the internal cavity is lined with cells that have each a flagellum and a collar

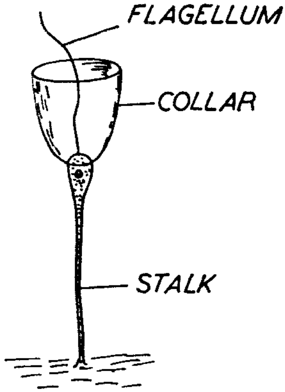


FIG. 9. A CHOANOFLAGELLATE, SHOWING STALK, COLLAR AND FLAGELLUM.

of protoplasm surrounding its base, very like the cells of the Choanoflagellata (Fig. 11).

The wall of the "vase" is perforated with a large number of small holes, through which water can enter the hollow interior, which is called the paragaster. The movement of the flagella of the collared cells lining the paragaster draws water in through the perforations, and the current of water is expelled through the opening at the top of the "vase"; this opening is called the osculum.

The water passing through into the paragaster of the sponge carries with it large numbers of tiny organisms, and these are taken in by the collared cells that line the paragaster. Just how they engulf the food is something that we are not yet certain of, but it is believed that the collars have something to do with it.

The olynthus, in common with all sponges, has one feature that is most unusual in the Animal Kingdom. The main opening of the body, the osculum, is not used, like a mouth, for taking things in, but for sending things out.

No adult sponge has such a simple structure as an olynthus. The body of the sponge may be branched many times, giving it something of the appearance of a bush, with an osculum at the tip of each branch. The wall of the paragaster also may be very complex, so that water passing through the pores has to make its way through a maze of passages before it reaches the paragaster

and is then expelled through the osculum. Apart from these complications, however, the general organization of a sponge is based on the same arrangement as is seen in an olynthus.

The body wall of a sponge is strengthened by means of a skeleton. In what are called the calcareous sponges, this consists of small, spiky fragments of calcium carbonate, secreted by cells that form part of the body wall. In other sponges, the skeleton may be silicious (flinty) instead of calcareous, and in the bath sponges it is, as we have seen, horny. If the living part of a bath sponge is allowed to rot, the horny skeleton is left.

Sponges are quite common, and may be found on rocky shores all round our coasts. The best place to look for them is in rock pools between the high- and low-tide marks. Sponges often form a crust covering the surface of a rock or stone under water, and

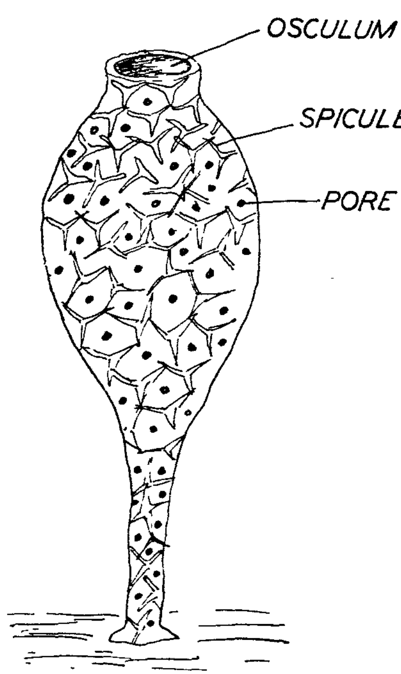


FIG. 10. THE OLYNTHUS STAGE OF A SPONGE.

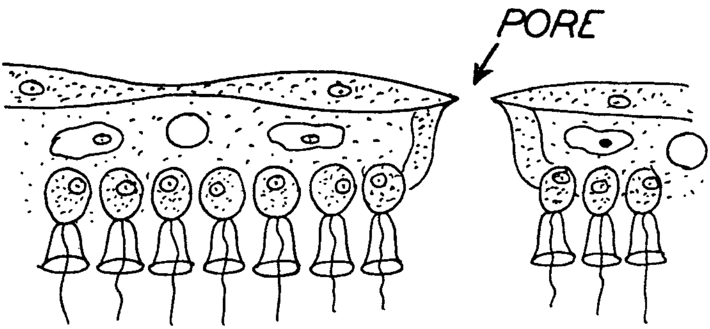


FIG. 11. PART OF A SECTION THROUGH THE WALL OF A SPONGE, IN THE REGION OF A PORE, SHOWING FLAGELLATED CELLS WITH COLLARS.

they may be brightly coloured: yellow, orange and red, according to the species. In these crust-forming sponges, the oscula can be seen on the surface, looking rather like volcanic craters. A common one is the crumb-of bread sponge (*Halichondria panicea*), which forms a yellow growth on the surfaces of stones in rock pools. Another common one is *Hymeniacidon sanguinea*; this is rather smaller than the crumb-of-bread sponge, and varies in colour from orange to red.

The boring sponge (*Cliona celata*) has the strange habit of boring into limestone rocks. It will also bore into the hard shells of molluscs, and sometimes does a great deal of damage in oyster beds.

The sponges are strange creatures, and they show a number of differences from all other animals. Although their bodies are composed of many cells, they are organized in a different way from the bodies of other many-celled animals. In particular, the cells of a sponge are not modified to form such things as a nervous system, blood vessels or the like. The cells of a sponge are mainly unspecialized, and able to change into various forms as need demands. This is not true of the cells of most other animals.

The sponges also differ from other many-celled animals in that the main opening in their bodies is not a mouth, but an opening through which water passes out of their bodies. The sponges are also the only group, apart from the Protozoa, in which collared

cells are found. For these and other reasons, the sponges are often put into a sub-kingdom of their own—the sub-kingdom Parazoa—to distinguish them from all other many-celled animals that are included in the great sub-kingdom Metazoa.

CHAPTER IV

TWO-LAYERED ANIMALS—PHYLUM COELENTERATA

If you bathe in the sea when you are on holiday, you have probably seen, at some time or another, those curious, semi-transparent, floating umbrellas called jelly-fish. You may even have been unlucky enough to feel their sting—an experience that you are not likely to forget, for it can be very painful.

Jelly-fish are not, of course, fish. They belong to a much simpler and more primitive group of animals, the Coelenterata. This Phylum also includes the sea-anemones, the corals, a rather unpleasant, though beautiful, creature called the Portuguese man-of-war, and a number of other less familiar animals.

The Coelenterata have bodies which consist, essentially, of two layers of cells. The outer layer is called the ectoderm, and the inner is the endoderm. Between these two cell layers is a structureless jelly called the mesogloea. This two-layered structure distinguishes the coelenterates from all the rest of the Metazoa or many-celled animals.

Most of the Coelenterata live in the sea, but there is one very common one that is found in fresh water. This is a strange little animal called *Hydra*, which is often seen attached to weeds in a pond. Like the sponges, *Hydra* is sedentary, spending most of its life attached to some solid object in water. There are several different species, and they vary in colour: green, brown or greyish-white.

Hydra is a small animal, and to make out its structure we really need a hand lens or, better, a low-powered microscope. It is a very simple creature. Its body is a long cylinder; the end that is attached is called the foot, and at the other end are about half a dozen long, slender "arms." These are the tentacles, and with

these *Hydra* catches the small animals on which it feeds. In the middle of the group of tentacles is the mouth (Fig. 12).

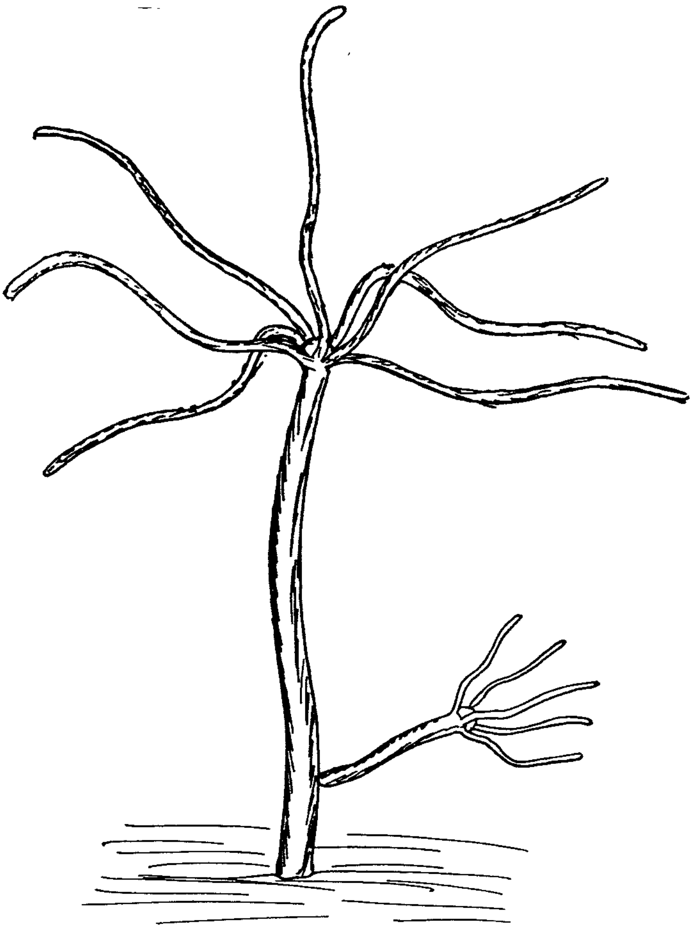


FIG. 12. *Hydra*, WITH BODY AND TENTACLES FULLY EXTENDED. NEAR THE BASE OF THE ANIMAL A BUD IS GROWING INTO A NEW INDIVIDUAL.

The body and tentacles of *Hydra* are very elastic. If you touch one of the tentacles lightly, the body shortens and thickens, and the tentacles contract to a fraction of their length. A harder buffet will cause the animal to contract into an almost spherical lump, the tentacles becoming no more than a crown of small

bulges round its free end. After a while, if left alone, the *Hydra* will stretch out again.

Although *Hydra* is a sedentary animal, that does not mean that it cannot move from place to place. It does so by bending over until the tips of its tentacles touch some solid object; it then moves the base of its body up to its tentacles and straightens out again. Sometimes it may perform a complete somersault on its tentacles, like a boy doing a "cartwheel" (Fig. 13).

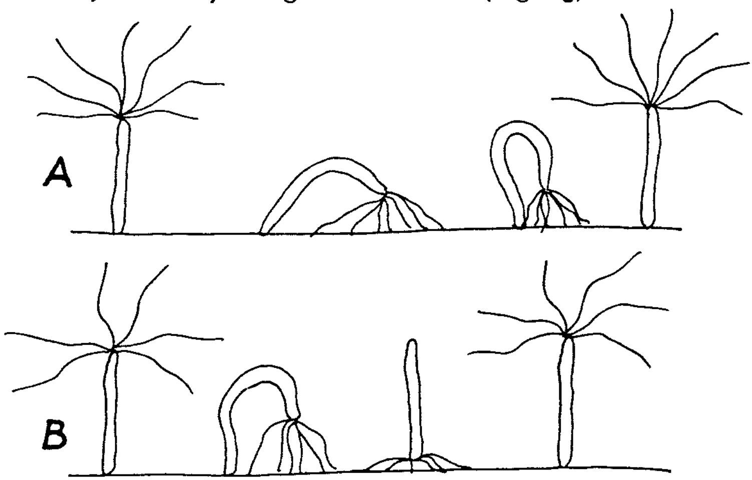


FIG. 13. MOVEMENT IN *Hydra*. A, LOOPING; B, SOMERSAULTING.

Hydra feeds on small water organisms, such as the "water fleas" that are abundant in any pond. It catches them with its tentacles. These are provided with stinging cells, called nematocysts, each of which contains a fine thread coiled up inside it. A nematocyst can fling its thread out violently, so that it acts rather like a harpoon. If the sharp tip of a thread penetrates the skin of a water flea, it injects a poison that paralyses the animal. The body of the prey is then carried by the tentacles to the mouth, which opens and swallows it.

The poison produced by the nematocysts is not a powerful one, and their main function is probably to hold the prey while it is being carried to the mouth. The fact that the prey is stunned, however, makes this easier. Some of the larger coelenterates, however, have powerful stings: that of the Portuguese man-of-war (see page 42) can be dangerous to man.

The water fleas eaten by *Hydra* are not really fleas, nor are they even insects. They are minute crustaceans, related more to the crabs and lobsters than to the true fleas.

Hydra feeds only when it is hungry; when it has had enough, a water flea will be ignored even if it touches the tentacles of the *Hydra*. You cannot bamboozle a *Hydra* into catching and swallowing such things as pieces of sawdust or cotton wool, but it can be deceived if the cotton wool is soaked in meat broth before it is offered. If the *Hydra* is hungry, it will start moving its tentacles as soon as food is brought near it. This seems to show that *Hydra* has something resembling a sense of smell.

Hydra reproduces in two different ways. In the simplest method, a bud grows out from its body, develops a mouth and a ring of tentacles, and breaks away to start life on its own. As no sexual process is used, this is called asexual reproduction.

In the other form of reproduction, male and female sex organs are formed. In the green *Hydra* (*Chlorohydra viridissima*) both kinds of sex organ are formed on the same animal, so that it is both male and female at the same time: we say that *C. viridissima* is hermaphrodite. In other species, a given animal has either male sex organs (testes) or female sex organs (ovaries), but not both.

The testes are usually formed on the upper part of the body, where they appear as small swellings. There may be several of them. The ovary, which is usually single, is formed lower down: it also is a swelling on the side of the body.

The testes produce the male sex cells or sperms. These are microscopic objects, each one appearing rather like a tadpole, with a head and a wriggling "tail" by which it swims. The ovary contains a single egg, which is spherical and very much larger than a sperm. When the egg is ripe it bulges through the wall of the ovary, still attached to the body by a short stalk. The sperms are set free from the testis into the surrounding water, swimming by means of their "tails" (flagella). One of them burrows into the egg, which is then fertilized.

The "head" of the sperm is really its nucleus. The egg, in spite of its large size, is a single cell, and has a nucleus. When a sperm fertilizes an egg, the two nuclei, sperm nucleus and egg nucleus, fuse together to form the single nucleus of the fertilized egg or zygote. This fusion of two cell nuclei to form one is the essential

part of sexual reproduction in all animals—and, for that matter, in all plants too.

After the egg has been fertilized, it begins to divide, forming a number of cells. These first cell-divisions of a fertilized egg are called cleavage. Soon a hollow ball of cells, called a blastula, is formed. A few more cell divisions follow, and then the embryo, as a young developing animal is called, becomes covered with a spiny outer coat and drops off the body of the parent. Protected in this way, it may be carried about by water currents, or even on the feet of birds or other animals, thus helping to secure dispersal. After some weeks, the embryo begins to grow again, bursts out of its protective coat, and develops into a young *Hydra.*

The green *Hydra* (*Chlorohydra viridissima*) has one interesting feature that is not shared by the others. If we examine it closely under a microscope, we can see that it owes its green colour to the presence in it of a lot of very small green cells. These are algae (microscopic plants), and they inhabit the body of the *Hydra,* living in partnership with it. These green cells are known as zoochlorellae.

Like all green plants, the zoochlorellae are able to manufacture sugar from carbon dioxide in the air, giving off oxygen as they do so. This animals cannot do. It is likely that the zoochlorellae supply the *Hydra* with sugar, receiving in turn carbon dioxide, which the animal produces by its respiration, and probably waste products containing nitrogen as well. Thus, both partners benefit. Such a relationship between two living organisms, where one inhabits the body of the other for mutual benefit, is called symbiosis.

If you examine seaweed from near the low-tide mark, you may find specimens of *Obelia* attached to the surface of the weed. This coelenterate looks like a tiny plant, an inch or so long; it may be branched near its tip, and along the main stem we can see what appear, to the naked eye, to be a series of buds.

To see *Obelia* properly we need a fairly powerful hand lens or, better still, the low power of a microscope. With this aid to vision we can see that what appeared to be buds are really *Hydra*-like heads, each with its crown of tentacles.

In Chapter III, I mentioned some curious stalked, sessile Protozoa called the Choanoflagellata, and pointed out that in some cases a number of these creatures were attached to a common stalk, forming a colony of animals. *Obelia* is another

instance of this. Each little *Hydra*-head on a specimen of *Obelia* can be regarded as an individual animal, known as a polyp, and all the polyps together, with their common stalk, make up a colony. The whole colony is called a hydroid (Fig. 14).

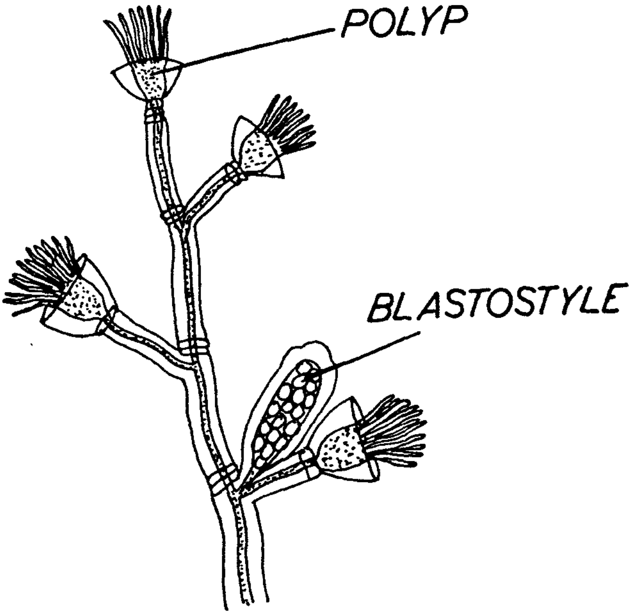


FIG. 14. PART OF A COLONY OF *Obelia*, SHOWING FOUR POLYPS AND A BLASTOSTYLE PRODUCING YOUNG MEDUSAE BY BUDDING.

Each polyp of an *Obelia* colony has much the same structure as a *Hydra*: there are certain differences, but we need not trouble ourselves with them. When we come to the reproduction of *Obelia*, however, we find that it behaves in quite a different way from *Hydra*.

You will remember that *Hydra* reproduces itself asexually by forming buds. *Obelia* does also, but in a different way.

If we look at an *Obelia* through a microscope, we can see a number of vase-shaped outgrowths, formed in the angles between some of the polyps and the main stem. These are called blastostyles. With the aid of the microscope, we can see that the surfaces of the blastostyle are covered with tiny round plates. These are the buds. They do not, however, grow into new polyps. Instead, each round, plate-like bud breaks away and swims off

on its own, like a tiny jelly-fish. This is called a medusa. It is very like the common jelly-fish of our coasts to look at, with a fringe of tentacles round its edge, but it is, of course, very much smaller, measuring only a fraction of an inch in diameter.

The medusa is shaped like an umbrella, with a large number of tentacles round its edge. Underneath, where the handle of the umbrella would be, there is a short stalk, at the tip of which is the mouth. The umbrella itself is thin and almost transparent, but it is crossed by four lines at right angles to one another (Fig. 15).

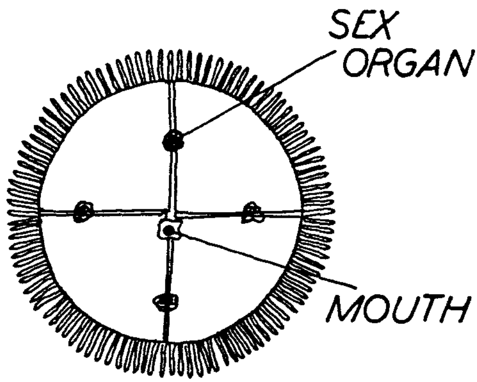


FIG. 15. MEDUSA STAGE OF *Obelia*, SEEN FROM BELOW.

These are the radial canals, that lead from the stomach, in the centre of the umbrella, to a ring canal that runs round the edge. On each of these radial canals we may see a small patch; these are the gonads or sex organs.

Now we come to the strange part of the story of *Obelia*. Sexual reproduction takes place in much the same way as in *Hydra*, but the fate of the fertilized egg is different. After fertilization, the egg develops into a tiny larva, shaped rather like a banana and covered with waving cilia (page 24). This is called a planula. It swims about for a time, using its cilia, and then, settling down with its broader end attached to a piece of seaweed, it grows into an *Obelia* colony.

We find, then, that *Obelia* consists of two animals in one: the hydroid and the medusa. Moreover, these two forms follow one another regularly in the course of the life history. The hydroid forms medusae by budding, and the medusae then give rise to more hydroids by sexual reproduction. The hydroid is the

asexual stage, reproduced by budding, while the medusa is the sexual stage. You *never* find a hydroid producing another hydroid directly, or a medusa producing another medusa: the two forms *must* alternate. This is called alternation of generations. It is very common indeed in plants, but very rare in animals.

Just now I spoke of the planula as being the larva of *Obelia*. The word "larva" is a very important one in zoology. We shall be using it a great deal, so we may as well make sure now that we know exactly what it means. When the young stage of an animal is quite different from the adult, we call the young stage a larva. A caterpillar, for instance, is the larva of a butterfly or moth. We do not call a kitten a larva, because it is quite obviously a young cat, even though it may have certain characteristics of its own, such as blue eyes. When a larva changes into an adult, it has to go through a period of drastic change, while it is acquiring its adult form: this is called metamorphosis.

The life history of *Obelia*, with its strange alternation of generations, will help us in understanding some of the other Coelenterata. In *Obelia* the alternation of generations is an easy one to follow, since the two generations are of about equal importance—using the word "importance" to mean how much of the whole life history each stage takes up. In most coelenterates, one generation takes up more of the life history than the other, and so is more obvious. We can regard *Hydra* as being an extreme case of this, the medusoid stage being left out altogether.

The common jelly-fish (*Aurelia aurita*) is an instance where the best-known part of the life history is the medusa. Few people know that the jelly-fish has a polyp stage at all. We have all seen the medusa stage, however, floating in the sea, like a pale, translucent umbrella. It is small, as jelly-fish go, seldom reaching more than a foot in diameter. Although well provided with nematocysts (stinging cells), these are not powerful enough to penetrate human skin with any ease, so that this particular jelly-fish seldom stings us. The larger jelly-fish *Chrysaora isosceles* is less friendly, for it can give us a nasty sting. It has triangular brown markings radiating from the centre of its umbrella like the spokes of a wheel, and long, trailing tentacles: we can thus recognize and avoid it.

Our largest British jelly-fish is *Rhizostoma pulmo*. This may reach a diameter of two feet, but, like *Aurelia*, it is harmless. We

also have two species of *Cyanea* that sting: *C. capillata* is yellow and *C. lamarcki* is blue.

In foreign waters, jelly-fish much larger than ours may be found. *Cyanea aurita*, for instance, may grow to six feet in diameter.

The hydroid stage of a jelly-fish is called a scyphistoma. It is found attached to rocks, and often to the wooden piles that support piers. The jelly-fish is the sexual stage in the life history and, as in the medusa of *Obelia*, its sexual reproduction produces a planula larva. This settles down on some solid object, such as a rock, and grows into a polyp with a crown of tentacles at its free end (Fig. 16). After a time, the tentacles are withdrawn and

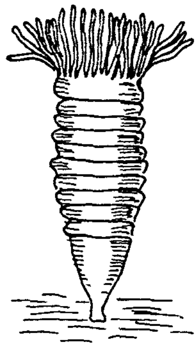


FIG. 16. SCYPHISTOMA STAGE OF THE JELLY-FISH.

replaced by eight blunt lobes; at the same time, the polyp becomes longer, and is then divided across by a number of rings. At this stage it looks rather like a pile of saucers. The top saucer then breaks away as a small jelly-fish with eight arms; the spaces between the arms fill in as it grows. Then the next "saucer" frees itself, and the next, and so on. This strange process is called strobilization.

From the jelly-fish, in which the medusa is the main stage in the life history, we turn to the sea-anemones, which have no medusa stage at all. They exist only as polyps. Sea-anemones are common in rock pools all round our coasts, and especially in the West Country, where the rocky shores provide them with an ideal home.

A sea-anemone consists of a single polyp, with a rather broad trunk and a dense crown of numerous tentacles, in the centre of which is the mouth. Many of them are beautifully coloured.

They are lovely objects when we can catch them undisturbed, but on being touched they quickly withdraw their tentacles.

Sea-anemones differ very much in their feeding habits. Some feed on plankton—minute organisms floating in the water. Their bodies are covered with waving cilia (page 24), which, by making currents in the water, help to guide the floating plankton towards the mouth. Other anemones are more ambitious. They can seize quite large animals in their tentacles, kill them, and eat them.

The corals are somewhat similar to the anemones, but, like *Obelia*, they are colonial animals. They have a hard skeleton of calcium carbonate. This may be situated in the mesogloea—the jelly that is sandwiched between the two layers of cells that make up the body of a coelenterate—but in the reef-building corals it is external, forming a sort of tube in which the animal lives.

The coral reefs in the Pacific are built up from the skeletons of millions of these tiny polyps. Corals are not confined to tropical seas: many occur in colder waters in the Northern Hemisphere, though they do not build reefs, and we have at least two species on the coast of Devonshire.

One of the strangest of all the coelenterates, and one of the most complex, is the Portuguese man-of-war (*Physalia physalia*). This is an occasional visitor to Britain from tropical waters, for from time to time specimens are stranded on the shores of Devon and Cornwall. They should be examined from a respectful distance, and not touched, for they possess the most powerful sting of all the Coelenterata. A sting from one of these animals is extremely painful.

The Portuguese man-of-war is a very complex colony, in which both hydroid and medusoid individuals are blended together. The top of the colony forms a large bladder (the pneumatophore) by which it floats, and a ridge along the top of the bladder acts as a sail. Beneath the bladder are the gasterozoids—the members of the colony whose duty it is to attend to the business of feeding (Fig. 17). Long tentacles hang down beneath the colony, and on these the powerful stinging cells are placed. The bladder is usually blue, tinged with pink and mauve, with perhaps a touch of orange; but the colour is very variable.

The sea-gooseberry (*Pleurobrachia pileus*) is sometimes to be seen in the water close to our shores, and may be found occasionally in rock pools. It is shaped rather like a gooseberry, with

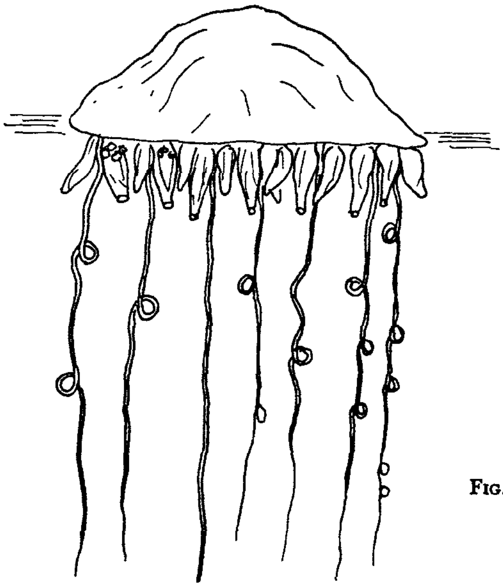


FIG. 17. *Physalia*, THE PORTUGUESE MAN-OF-WAR.

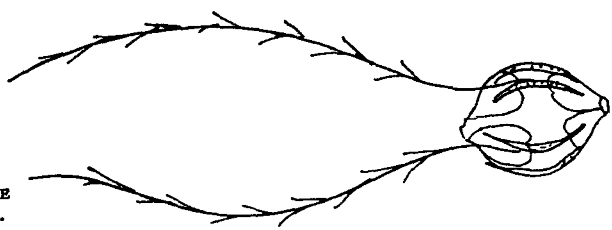


FIG. 18. *Pleurobrachia*, THE SEA GOOSEBERRY.

a mouth at one end. It swims by the vibration of cilia in eight "combs" or swimming plates set along its sides (Fig. 18). Two long tentacles trail behind it as it swims. It has no stinging cells.

The sea-gooseberries differ in some important ways from other Coelenterata, i.e., in the absence of stinging cells, and in the use of cilia for swimming. They are placed in a sub-phylum of their own, known as the Ctenophora.

There is one important feature of the Coelenterata that I have not yet mentioned. They are radially symmetrical: that is, like a wheel, they have no right and left. Most animals are *bilaterally symmetrical*: they have definite right and left sides to their bodies. We shall come across radial symmetry again later on, when we talk about the starfish and its allies.

CHAPTER V

FLATWORMS AND ROUNDWORMS—PHYLA PLATYHELMINTHES AND NEMATODA

ALMOST any animal with a long thin body and no obvious limbs is liable to be called, at some time or another, a "worm." Thus, we have the slow-worm (a kind of lizard), the wireworm (the larva of a click beetle), the earthworm, the tapeworm and the eelworm. Only the last three are worms in the zoological sense, and even they are only distantly related to one another, if they are related at all.

In this chapter I am going to talk about two kinds of worms—the flatworms (Platyhelminthes) and the roundworms (Nematoda). The earthworms and their allies of the Phylum Annelida we will leave until a little later.

The Flatworms

One of the best known of the flatworms is the liver fluke (*Fasciola hepatica*). This is a parasite that may affect sheep if they are kept in damp pastures.

The liver fluke is not much like a worm to look at. When fully grown it is flat and more or less oval in outline, brown in colour, and an inch or so long (Fig. 19). It looks something like a small leaf. At the broader end is the mouth, lying in the centre of a sucker by which the animal can attach itself. There is another sucker on one side, a little way back from the mouth. Between these two suckers is the genital opening, through which the eggs pass out of the body after fertilization.

The adult fluke inhabits the liver of a sheep, where it is found in the tubes (bile ducts) that carry the bile, produced by the liver, to the intestine. The fluke causes in the sheep a disease called

"liver rot." This includes loss of wool, dropsy and general ill health, and is often fatal.

The liver fluke mainly affects sheep, but it can inhabit other animals, including cattle and even man.

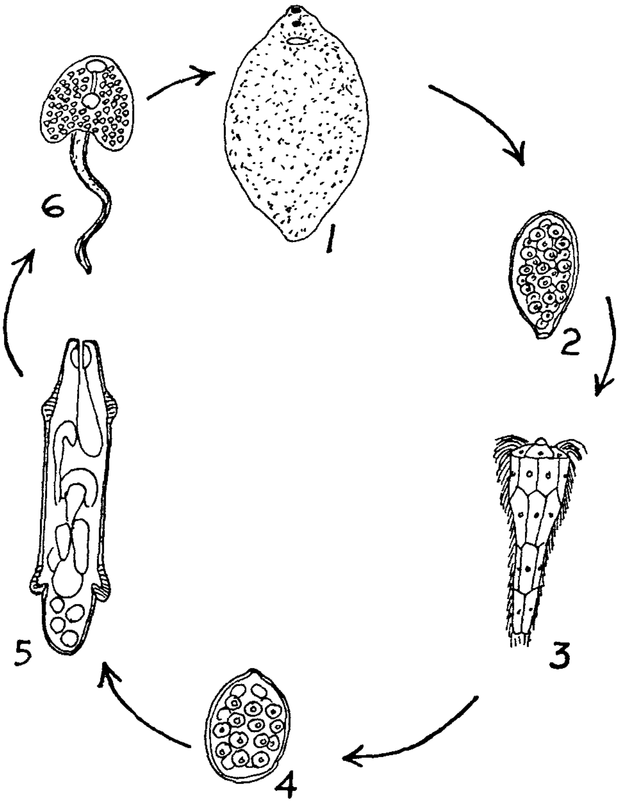


FIG. 19. THE LIFE HISTORY OF THE LIVER FLUKE. 1, ADULT; 2, EGG; 3, MIRACIDIUM; 4, SPOROCYST; 5, REDIA; 6, CERCARIA.

The life history of the liver fluke is interesting and very complex. The adult fluke lays its eggs in the liver of the sheep, and as long as they remain in the sheep they do not hatch. Eventually, however, the eggs travel down the bile duct from the liver to the intestine, with the bile, and, moving down the intestine, they eventually leave the sheep with the droppings. Once outside, if

conditions are sufficiently warm and damp, the eggs hatch into tiny larvae, called miracidia.

The miracidium is conical, and a little more than a tenth of a millimetre long. At the broad end of its body it has a crown of cilia, by which it can swim; at this end there is also a spike that can be pushed out.

The miracidium will develop no further unless, in the course of its swimming, it can find a water snail called *Limnaea truncatula*. If this happens, the miracidium bores its way into the body of the snail with a rotating motion, using the spike on its head as a drill.

Inside the body of the snail, the miracidium loses its cilia, increases in size somewhat, and becomes a hollow, oval bag called a sporocyst. Inside this, certain cells begin developing into larvae of another kind, called rediae. These are finally set free by the bursting open of the sporocyst.

The redia has an elongated body with a mouth at one end. When they are free from the blastula, the rediae begin to eat the body of the snail, and finally kill it. The rediae are able to reproduce themselves, so that there are several generations of them in the snail. Finally, the rediae produce yet another kind of larva, called the cercaria. This is shaped rather like a minute tadpole, with a heart-shaped body and a long tail. A cercaria is about one third of a millimetre long.

The cercaria comes out of the body of the snail, swimming like a tadpole by means of its tail. It settles itself on a blade of grass, where it loses its tail and surrounds itself with a protective wall called a cyst. The cysts are eaten by sheep, and in this way the sheep are infected.

This is a very complicated life history. Besides having several different larval forms, the liver fluke has two hosts, as the animal or plant inhabited by a parasite is called. Both hosts are necessary : the eggs of the fluke cannot harm a sheep until the parasite has passed through its larval stages, and these need the snail. This may remind you of the life history of the malarial parasite, where both man and mosquito are needed to complete the cycle.

We see now why damp pastures are dangerous for sheep, for only under damp conditions can the rediae of the liver fluke swim. *Limnaea truncatula*, moreover, is a water snail. The best way of avoiding liver fluke in sheep, therefore, is to keep pastures well

drained. Many harmful parasites can be dealt with in this sort of way—by making conditions unsuitable for some stage in their life histories.

The tapeworms are parasitic flatworms of a very different kind from the liver fluke, though they belong to the same Phylum. There are many different tapeworms, affecting various animals; a common one in man is *Taenia solium*.

This parasite lives in the human intestine. It has a head, with four suckers and a crown of hooks, and a narrow neck to which the flattened body of the worm is attached (Fig. 20). The body of the tapeworm consists of a large number of flattened, rectangular segments, called proglottides (singular, proglottis). A large

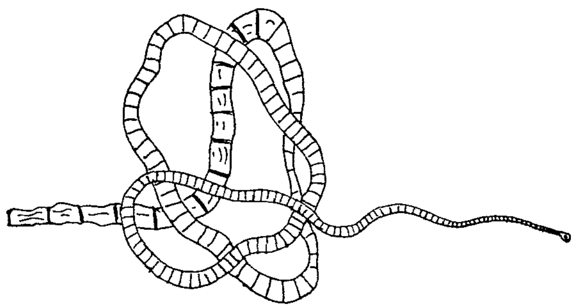


FIG. 20. AN ADULT TAPEWORM.

specimen may be twenty feet long, with more than 1,000 body segments.

The tapeworm grows from its neck, which is constantly forming new proglottides. The youngest proglottides are therefore nearest the head, and they get older as we pass backwards along the body.

The tapeworm has no gut: bathed constantly in the food in the gut of the host, it does not need one, since it can absorb nutriments all over its body. It does, however, have a very simple nervous system, and also reproductive and excretory organs. Each proglottis has its own set of excretory and reproductive organs, and is hermaphrodite—male and female at the same time.

The tapeworm produces enormous numbers of eggs. In *Taenia solium* there is usually only one worm per host, so we must presume that it fertilizes itself. The oldest proglottides—

those at the "tail" end of the body—are packed with fertile eggs, often as many as 850,000 in a single proglottis. As the proglottides at the end of the body age, they break away one by one, and pass out of the host's body with the excrement.

The next stage in the life history of *Taenia solium* depends on the eggs being swallowed by a pig. If that happens, the egg hatches into a tiny embryo called an onchosphere. This is spherical, and is provided with six hooks.

When the onchospheres are set free in the intestine of the pig, they bore through the wall of the intestine into the blood vessels, and are carried by the blood to the muscles and elsewhere. Embedded in a muscle, an onchosphere loses its hooks, becomes larger, and is then called a bladder-worm or cysticercus. The flesh of pigs infested with bladder-worms is popularly known as "measly pork." If this is eaten by man and if the cooking has not been sufficient to kill the bladderworms, they will develop into tapeworms when they reach the human gut.

Unlike the liver fluke, *Taenia solium* does not produce severe illness in its host, though harbouring a twenty-foot tapeworm is not to be recommended. Tapeworm and host may live together for many years.

The flatworms are not all parasites. Some of them, known as turbellarians, are free-living. Most of them feed on dead animal matter, sucking in their food with a mouth on the end of a tube (the pharynx) that can be stuck out from the lower side of the body, like a vacuum cleaner (Fig. 21).

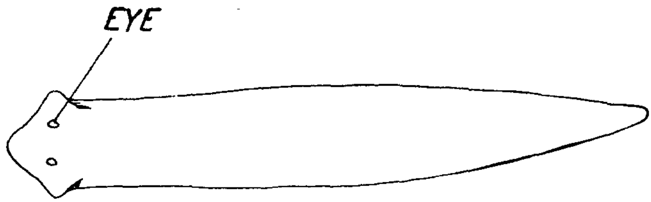


FIG. 21. A TURBELLARIAN WORM.

Turbellarians have a remarkable power of regeneration: that is, when they are cut into pieces, each piece can grow into a whole animal. Another curious feature is that, if they are starved, they de-grow, becoming smaller and smaller and losing some of their internal organs.

1. The ragworm (*Nereis*). Note the lines of parapodia running down the sides of the animal.

2. The sea mouse (*Aphrodite*), upper surface.

3. The sea mouse (*Aphrodite*), lower surface. Note the parapodia, and compare with Plate 1.

4. *Ligia oceanica*, THE SHORE SLATER, A MARINE CRUSTACEAN.

5. THE KING-CRAB (*Limulus*), SEEN FROM ABOVE.

6. THE CUTTLEFISH, *Sepia officinalis*.

The Roundworms

The Nematoda or roundworms have slender, rounded bodies, with pointed ends. Many are parasitic in man or animals, and many of the smaller ones are important parasites of crop plants. The group also includes forms that are free-living and harmless.

Some of the roundworms are quite large; *Ascaris lumbricoides*, a parasite of man in warm countries, may be ten inches long. The "worms" that affect cats and dogs in this country are roundworms. From the economic point of view, however, the most important roundworms are the small ones that attack plants. These are known as eelworms, from their eel-like movements as seen under a microscope.

Most of the plant-parasitic eelworms are no more than a hundredth of an inch long, and so are virtually invisible to the naked eye, but they exist in countless numbers, and the damage they do to crops is stupendous. The potato root eelworm (*Heterodera rostochiensis*) alone costs Britain about £2,000,000 a year by the destruction it does in potato fields. Eelworms are worldwide, and there are few crops, if any, that they cannot attack.

CHAPTER VI

ROTIFERA AND POLYZOA

IN this short chapter I want to say something about two groups of small aquatic animals that are not at all uncommon, though they escape notice because of their small size. The rotifers and polyzoa are not closely related to one another, but it is convenient to consider them here under one heading.

The Rotifera

The rotifers are sometimes called "wheel animalcules," for a reason that will appear presently. They are minute fresh-water animals, common in ponds and streams. Some move about freely, while others are sedentary, living in tubes attached to pieces of wood or plants submerged in water. Rotifers are beautiful objects when seen under a microscope, and are popular objects of study with microscopists.

Rotifers vary very much in shape. They get the name "wheel animalcule" from the double ring of hair-like cilia surrounding the mouth at the head end; the waving motion of the cilia produces currents in the water, sweeping food into the mouth. Seen under the microscope, the rapid waving of the cilia gives the impression of a rotating wheel. This is a characteristic feature by which rotifers may easily be recognized.

Although rotifers are very small, they are multicellular animals with quite a complex structure. Their tiny bodies contain a stomach and intestine, and also excretory and reproductive organs.

The reproduction of rotifers is somewhat unusual. The females are larger than the males, and in some species of rotifers there are no males at all, the eggs developing without fertilization.

There are usually two kinds of female rotifers. One kind produces eggs that develop without being fertilized by the male, and these eggs produce more females. The other kind of female rotifer produces eggs that develop into males, again without fertilization; these male-producing eggs are often smaller than those that produce females. The second type of female also produces eggs that are fertilized by the male rotifers, and these fertilized eggs develop into females. The life history of the rotifer is thus somewhat complicated.

The Polyzoa

The Polyzoa or "sea-mats" are nearly all marine, though there are a few fresh-water forms. The old group of Polyzoa has now been divided into two quite separate Phyla, the Ectoprocta and the Endoprocta, and these are probably not at all related to one another, but that need not concern us here; for convenience, I am going to group them together as Polyzoa.

The structure of a typical polyzoan reminds one of the colonial coelenterates such as *Obelia* (Chapter IV), but there are important differences. Like *Obelia*, the Polyzoa are colonial animals. The colony is enclosed in a supporting skeleton, usually made of a horny substance, though in some species it is hardened with calcium carbonate. The skeleton forms a series of boxes, each box being inhabited by an animal. The Polyzoa do not show the close connexion between the neighbouring members of the colony that is such a remarkable feature of *Obelia* and other hydroids.

The box-like compartments of a polyzoan colony are called a zooecia. Each member of the colony has a mouth, surrounded by a ring of tentacles, which can be drawn back within the zooecium if the animal is disturbed. The mouth leads to a simple gut within the animal. This is curved in the form of a U, and opens again to the exterior by a hole called the anus, near to the mouth. Through this opening, undigested food is expelled, after passing through the gut.

The tentacles are covered with cilia, the waving movement of which creates water currents that sweep food particles into the mouth. The passage of the food through the gut is also assisted by cilia.

Polyzoa are common animals on rocky coasts, where they cling to rocks between the tide marks. They may also cover the surfaces of fronds of the larger seaweeds, such as *Laminaria*. The colonies often form a crust over the surface on which they are growing—hence their popular name "sea-mat."

Fresh-water Polyzoa may be found growing on wooden piles supporting bridges, the submerged parts of boathouses, and in similar places. When gently scraped off their support, the colonies usually collapse into a shapeless jelly, and must be left in water for an hour or so to recover before they regain their natural appearance.

CHAPTER VII

SEGMENTED WORMS—PHYLUM ANNELIDA

We now come to the important Phylum that contains the earthworms and their allies. If we look at an earthworm, we can see at once why this group is called the Annelida (*annulus*, a ring), for the body of the worm is marked out with about 150 rings, one behind another. This segmentation by rings is characteristic of the Annelida.

A common earthworm in this country is *Lumbricus terrestris*. Specimens can be found by digging in any garden, and a large one may reach a length of about seven inches. The body is long and slender, and divided, as we have seen, into about 150 ring-like segments. The front end of the worm is sharply pointed, and the tail is flattened. About one-third of the way back from the head end is a swelling called the saddle or clitellum. This, as we shall see later, is concerned with reproduction.

The earthworm is brown in colour, often with a purplish tinge. It is darker on the upper side. The skin shows iridescent colours, like mother-of-pearl; this is because its cells secrete a covering (cuticle) of a substance called collagen.

If you gently pull an earthworm backwards through your fingers, you will notice that it feels rough, in spite of its smooth skin. This is because each segment has four pairs of bristles, called chaetae or setae, that stick out in four lines running down the body. The chaetae are made of a horny substance called chitin; the same material also forms the hard outer skeleton of an insect. The chaetae, by enabling the earthworm to get a grip on the soil, help it to move from place to place. If you have ever tried to pull a worm out of the soil when it is half buried, you will realize how tightly it sticks.

An earthworm has no head. At the front end is the mouth,

shaped like a crescent, and overhung by the first segment of the body, which is called the prostomium. The mouth leads into the gut, a tube that runs the whole length of the worm's body, opening at the hinder end by an aperture called the anus.

To see the arrangement of the internal organs of the earthworm, we must open its body. This is easily done by slitting the worm along the middle of its back, after killing it with chloroform. The dissection is best done under water, so that the delicate structures inside the worm are supported. A flat pie-dish, with wax, or a piece of weighted cork mat, in the bottom, makes a good dissecting dish; the dead worm can be pinned out, slightly stretched, with a pin at each end, and covered with water. The cutting can be done with a fine, sharp pair of scissors, and care must be taken not to dig the point of the scissors in deeply enough to puncture the gut that lies beneath the body wall. After cutting, the body wall of the worm can be folded back and pinned down, out of the way.

If we dissect a worm in this way, we can see that the gut that runs down the middle of the body is divided into a number of definite regions: pharynx, oesophagus, crop, gizzard and intestine, as we pass from the mouth backwards. We also see that the inside of the body is divided by a series of partitions into a number of compartments—one for each of the rings on the outside. Each compartment (segment) contains a pair of excretory organs, by which the worm gets rid of waste nitrogenous substances, and a portion of the gut. Some of the segments near the front of the body also contain the reproductive organs, but these, and the excretory organs, are too small to be seen easily without a powerful hand lens.

You can now see what is meant when we call the earthworm a segmented worm. The body is divided into segments, one behind the other, each one partly, but not completely, repeating the structures in the one before. This kind of segmentation is very common in animals, though it seldom shows itself so clearly as it does in the earthworm. You yourself are segmented to some extent: the bones of your back (vertebrae) repeat one another, one behind the other.

The body wall of the earthworm is well supplied with muscles, for the earthworm is an active animal. If you put a worm on a flat surface, you can easily see the muscular movements. These

result in a sort of concertina action: waves of contraction pass down the body, one after another. This kind of movement is called peristalsis, and it resembles the movement of our own intestines as they force the food along.

If the worm is on a smooth surface, its peristaltic movements do not produce much progress, but if the surface is rough, so that the chaetae can grip, the worm can cover the ground quite efficiently. Notice how quickly a worm will disappear into the ground if it is disturbed: you need to be quick with your hand if you want to catch it.

Earthworms are some of the commonest of animals. They are to be found in nearly all fertile soils, but they are absent from some of the very acid soils that contain sour humus of the kind known as mor. They are usually found fairly near the surface, where they live in burrows lined with slime produced by glands in their skin. The opening of the burrow may be protected by the soil that is thrown out when the worm burrows its way into the ground (the worm cast), or it may be closed up with small stones, or even a leaf that the worm has pulled into the hole after it. If a leaf is used, the worm usually takes care to pull it into the hole narrow end first, so that it enters easily. Not all worms throw up worm casts; in fact, only two of our British species do so. The others get rid of the excess soil that they have swallowed below ground.

Worms do not like to emerge from their burrows in dry weather, or during severe frosts. During such times they remain snugly buried in a tiny cave, deep in the soil. The cave is lined with small stones.

On warm nights, if it is not too dry, the worm will partly emerge from its hole, but it keeps its hinder part buried so that, on the approach of danger, it can quickly draw back into its burrow. Worms do not often leave their burrows. If the weather is very wet they may be driven out by flooding; otherwise they normally stay where they are. Worms that are seen wandering on the surface of the soil in dry weather have probably come up to die, for it will usually be found that they are victims of parasitic maggots—the larvae of a kind of fly.

Earthworms do not have well-developed sense organs such as eyes or ears. They are sensitive to light, though they cannot see,

and they have a sense of smell. They cannot hear as we can, but they are very sensitive to vibrations in the ground.

Earthworms feed on the organic matter in the soil. They also eat leaves, and will even take animal remains; they are supposed to have a great fondness for fat. In feeding, a worm swallows soil through its mouth; as the soil passes along the gut, food material is taken out of it, the remainder passing out through the anus.

Earthworms are hermaphrodite (see page 47). Although they have both male and female reproductive organs in the same body, however, they do not fertilize themselves. At the time of breeding, two worms lie side by side, and male sex cells (sperms) are passed from each to the other. This happens in warm, damp weather, usually in summer. The worms then separate, and each one, by means of the glandular cells on its clitellum, spins an elastic belt round itself. The worm then slips this elastic band forwards over its head, like a boy taking off a rugger jersey. As the belt passes over the openings of the sex organs on its way forwards, it receives first eggs, and then sperms *from the other worm*, which have been held in a sort of pouch in the body. The band then slips over the worm's head, and forms a cocoon round the fertilized eggs. The cocoon lies in the soil while the eggs develop. Usually only one egg hatches, although there may have been anything up to sixteen eggs in the cocoon.

Some earthworms—though not *Lumbricus terrestris*—have considerable power of regeneration (see page 48). If such a worm is cut in half, both ends will live and grow the missing part.

Earthworms have an enormous influence on the soil, and on life in the soil. As they burrow, they are constantly swallowing soil and passing it out behind them, and those that form worm casts are continually bringing soil up to the surface from below. In this way they may bring up as much as twenty-five tons per acre in a year.

Besides mixing up the soil in this way, earthworms benefit plant life by keeping the soil open and letting in air and water. They also make the soil easier for the roots of plants to penetrate.

Earthworms have an important effect on the formation of soil. Their burrowings allow water and air to reach the rocks that lie beneath, and so hasten their disintegration to form soil. Worm casts brought to the surface may dry and crumble, and the fine soil so formed may be blown away by wind or washed away by

water. On sloping ground, the activities of earthworms may result in the gradual levelling of hills by this process of erosion.

The earthworms do not make up the whole of the Annelida. Some of the most interesting of the annelids are to be found on the sea shore. Most of these marine worms belong to a different group of annelids from the earthworm, called the Polychaeta. As the name implies, these worms have a larger number of chaetae than the earthworms, and for this reason they are popularly known as bristle-worms. A common example is *Nereis*, the rag-worm, often used as bait by sea fishermen.

Nereis burrows in muddy sand, where there is plenty of organic debris, and is usually found under stones on the sea shore. It resembles the earthworm in its rounded, slender, wriggling body, but here the resemblance ends. Running along the two sides of the animal we find a series of blunt out-growths, the parapodia, in which the chetae are mounted (Plate 1). There is a pair of parapodia to each segment, one on each side, and each parapodium is split into two main lobes, an upper and a lower, each of which is further divided into smaller lobes. Each of the main lobes bears a tuft of chaetae.

Unlike the earthworms, *Nereis* has a definite head. The prostomium, which in the earthworm is a small segment overhanging the mouth, in *Nereis* bears two pairs of eyes, a pair of tentacles and a pair of thick, blunt outgrowths called palps. The segment that surrounds the mouth—called the peristomium—carries a pair of long thin outgrowths, the tentacular cirrhi.

The complications at the front end of *Nereis* do not end here. *Nereis* is not content, like the earthworm, to scratch a meagre vegetarian existence by swallowing soil and absorbing the organic matter it contains: *Nereis* is carnivorous, catching and eating other small creatures. Its method of seizing its prey is unusual. The front end of the gut, called the pharynx, can be turned inside out, protruding through the mouth (Fig. 22). The lining of the pharynx is provided with small teeth, and also a pair of jaws with which the prey is grasped and drawn into the mouth as the pharynx returns to its normal position.

Nereis is but one of many strange and often beautiful polychaete worms that can be found on the sea shore. Some of these, the tube-worms, live more or less permanently in small tubes, only their heads projecting from the opening. The sand-mason

(*Lanice conchilega*), for instance, builds itself a tube from grains of sand. It is usually found on sandy beaches, fairly near the low-tide mark, where the top of the tube may be seen projecting from the sand; the worm itself will be withdrawn right into the tube, away from prying eyes.

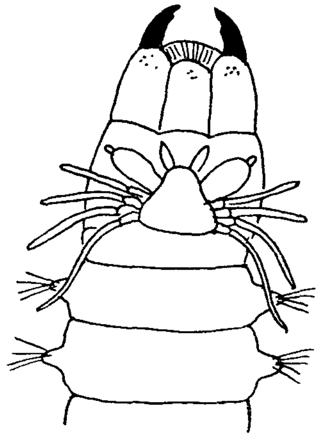


FIG. 22. HEAD OF THE RAGWORM (*Nereis*), WITH PHARYNX PROTRUDED SHOWING JAWS.

If you have ever walked on a sandy beach at low tide, you must have noticed the worm casts that appear here, there and everywhere. These will almost certainly have been made by the lug-worm or lob-worm (*Arenicola marina*), a very common inhabitant of sandy shores. This is not a tube-worm, for it does not form a tube, but it does the next best thing: it makes a firm burrow in the sand and stays there, feeding like an earthworm by swallowing sand containing organic matter. *Arenicola* is a large worm, up to nine inches long, and is popular with anglers as bait, as its soft body is very palatable to fishes.

One of the strangest and most beautiful of all the polychaete worms is the sea-mouse (*Aphrodite aculeata*). Nobody who saw this creature for the first time would ever connect it with the worms, for nothing could look less like an annelid. *Aphrodite* (Plates 2 and 3) has a body that is oval in outline, broad and flat, and a large specimen may be six inches long and two inches

wide. The animal is covered with long, fine bristles that look like hairs, from which it no doubt gets its name. *Aphrodite* lives on the sea bottom, buried in the sand, with only its hinder end exposed. Usually it is found below the low-tide mark, and so is not a common object of the shore, though sometimes specimens may be thrown up on the beach by storms.

No account of the annelids would be complete without mentioning the leeches. These belong to a different group of the Annelida from either the earthworms or the bristle-worms. The best known is the medicinal leech (*Hirudo medicinalis*), which lives in fresh-water ponds and marshes. It is rare in this country, though it is still to be found in some places, including the New Forest and the Lake District.

Hirudo medicinalis is a blood-sucker. It normally lives on the blood of cold-blooded water animals such as frogs and fishes, but it will also suck blood from warm-blooded animals, and it will take human blood if the skin is pricked first.

The leech has a rather flattened body, with thirty-two segments, though the number of rings on the outside of the body is three times as many as this. It has a sucker at each end, the mouth being in the middle of the forward one.

In former days, it was common medical practice to bleed sick people, and for this purpose leeches were often used. That is why today a doctor is often colloquially known as a "leech."

CHAPTER VIII

JOINTED ANIMALS—PHYLUM ARTHROPODA

THE *Phylum Arthropoda* is the biggest in the Animal Kingdom, and one of the most important. It includes the crabs, lobsters and shrimps (Crustacea): the centipedes and millepedes (Myriapoda), the insects (Insecta), the spiders, scorpions and king crabs (Arachnida), and a number of other smaller groups.

The word Arthropoda means "jointed limbs," and this is one of the main features of the Phylum. If you look at the legs of an insect, spider or crab, you will notice that each limb consists of several portions jointed together. In this way we can often recognize an arthropod without further examination—though I must warn you that this method of recognition is by no means infallible.

There are certain other things that most arthropods have in common. One is the hard outer skeleton that encloses the body. The exoskeleton, as it is called, is composed of a substance called chitin, and serves to support and protect the body, and to provide a firm framework to which the muscles can be attached.

The bodies of arthropods are segmented. Sometimes this is quite obvious, but it may be obscured by some of the segments either being fused together, or covered over by other structures, such as wings, wing cases, etc.

Each segment may bear a pair of appendages, one on each side, though these may be missing from some segments. The legs of an insect are examples of appendages. Appendages are not only used for walking, however: the jaws of arthropods are formed from appendages, and so are various other structures.

There is another feature of the structure of the Arthropoda that is not quite so easy to understand and observe. In most animals, such as the earthworm and other annelids, the various

organs of the body, such as the gut, lie in a hollow space inside the body, called the body-cavity or coelom. In the Arthropoda the coelom is so small that it is quite inconspicuous, and its place is taken by the blood-cavity, or haemocoele, in which the blood circulates.

The Arthropoda are very complex animals, with a high level of development. They show a wide range of structure among their various groups, and they are found in practically all parts of the world, in a great variety of different kinds of situations—below ground, on the surface of the land, in fresh water, in the sea and in the air. In the efficiency with which they have adapted themselves for life under all sorts of different conditions, as well as in their very large numbers, we must regard them as a highly successful Phylum.

There are so many different kinds of Arthropoda that to give anything like an adequate account of them in a single chapter would be quite impossible. Here I can do no more than try to give you some idea of the enormous variety of animal life contained in this great Phylum.

The Crustacea

The English crayfish (*Astacus pallipes*) is a typical example of a crustacean—as far as any member of this varied group can be called "typical." It lives in rivers, especially those with an origin in chalk or limestone.

A crayfish looks very much like a small lobster, about three inches long and greenish in colour. Like a lobster, it has a hard outer covering to its body, which is divided into three regions—head, thorax ("chest") and abdomen. In the region of the abdomen it can be clearly seen that the body is segmented, but the three segments of the thorax are hidden on top by a hard cover, the carapace: moreover, the segments composing the head and thorax are fused together, forming the cephalothorax, so that the segmentation of these regions is not at all obvious.

The head of the crayfish bears two pairs of "feelers": one pair, the antennules, quite short, and the other, called the antennae, long. At the base of each antennule is a small cavity, lined with sensitive hairs, and containing grains of sand that the crayfish puts there itself by scattering sand over the opening with its

pincers. It seems likely that the movement of the sand grains against the sensitive hairs of the cavity gives the animal a sense of position, and so helps it to keep its balance.

The head also bears a pair of eyes, which are carried on stalks. These are compound eyes: that is, each is made up of a large number of facets, each of which has its own lens and can form a separate image of what is seen.

The mouth is on the underside of the head. The crayfish does not chew its food in the same way as we do, as it has no teeth. Near the mouth, however, there are two pairs of appendages (see page 60, called the mandibles and the maxillules, and these are used to break up the food and push it into the mouth. The food is further broken up, after swallowing, by teeth in the front part of the stomach, which is known as the mill chamber.

The thorax of the crayfish bears eight pairs of appendages. The front three pairs, called maxillipeds, are concerned with feeding and respiration. Behind these are the pincers, the largest of the appendages, which are used for fighting and for grasping objects. The last four pairs of thoracic appendages are the walking legs.

The crayfish breathes by means of gills. These are feathery structures, contained in a gill cavity on each side of the thorax. A current of water passes through the gill cavity, and the oxygen dissolved in the water is extracted by the blood in the gills.

Crayfish live in small burrows that they make in the banks of rivers. They are nocturnal animals: they avoid strong light, remaining in their burrows during the day and coming out at night. They eat almost any kind of organic matter, either dead or alive, and their prey may include such things as newts, tadpoles, the larvae of aquatic insects, and the bodies of dead water animals. They can often be caught by baiting a stick with a piece of rotten meat and thrusting it into their burrows: the crayfish seize the meat and can be pulled out of their holes, as they are unwilling to let go.

The mating season for crayfish is in the autumn, and the eggs hatch in the spring. The young are very much like the adults, but very small, and for a time they cling to the abdominal appendages (swimmerets) of the mother, thus gaining protection and avoiding being swept away by water currents that might carry them out to sea where, being fresh-water animals, they would die.

The crayfish belongs to the group of Crustacea known as the Malacostraca. This also includes the lobsters, crabs, shrimps, prawns and woodlice, and is regarded as the most highly developed class of the Crustacea. Other classes of Crustacea include the water flea (*Daphnia*), the small fresh-water crustaceans such as *Cyclops*, and the barnacles that we see attached to rocks at the seaside and to ships' bottoms. A very interesting crustacean is *Sacculina*, which is parasitic in crabs. It is related to the barnacles, and is so much specialized for its parasitic life that its consists of little more than a bag with long suckers that penetrate throughout the body of its host.

It is difficult to imagine that the barnacles and *Sacculina* are really Crustacea, but we can see the relationship clearly if we study their larvae instead of the adults. These are of the type known as the nauplius larva, consisting of an unsegmented body with three pairs of appendages and a single eye (Fig. 23). This kind of larva is peculiar to the Crustacea.

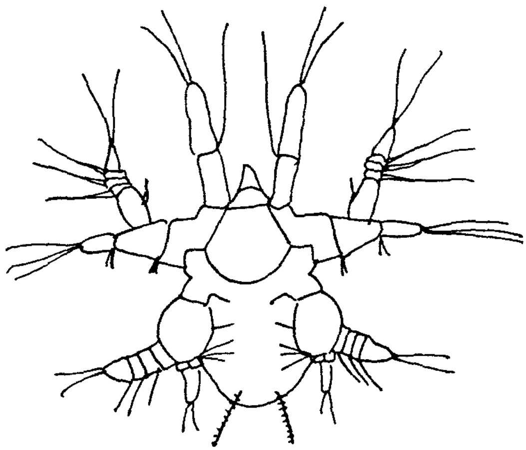


FIG. 23. NAUPLIUS LARVA OF THE WATER FLEA *Daphnia*.

The Insecta

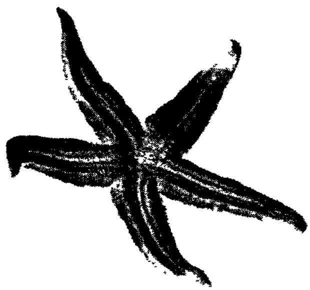
The Insecta are the most familiar group of the Arthropoda, and also the largest. They are one of the most successful groups in the Animal Kingdom, for insects are found almost everywhere, and often in very large numbers.

We can recognize an insect with great ease by its arthropod type of body, with jointed limbs, its hard outer skeleton, and by the fact that it has three pairs of legs. This last character will distinguish an insect from other arthropods.

Insects have a peculiar method of breathing. The body of an insect contains a system of very fine tubes, called tracheae. These are connected with a series of openings, the spiracles, running along both sides of the body. Air enters through the spiracles, and is carried by the tracheae to all the cells of the body, supplying them with oxygen for respiration. In insects, the oxygen needed for respiration of the cells is not carried by the blood, as it is in most other animals.

Many insects have complicated life histories. In the more advanced groups of insects, the life history runs through four definite stages: egg, larva (chrysalis), pupa (grub) and imago (adult insect). In the familiar cabbage white butterfly, for instance, the eggs hatch into caterpillars. These are quite unlike butterflies, and are therefore called larvae. The larvae feed and grow: when they reach full size they pupate, enclosed within a silken cocoon. During the pupal stage the insect does not feed: everything is apparently at rest, but actually, within the pupa case, there is much activity, for the insect is changing from its larval to its adult form, and this means a complete reorganization of its structure, both outside and inside. When this great change is complete, the adult insect emerges.

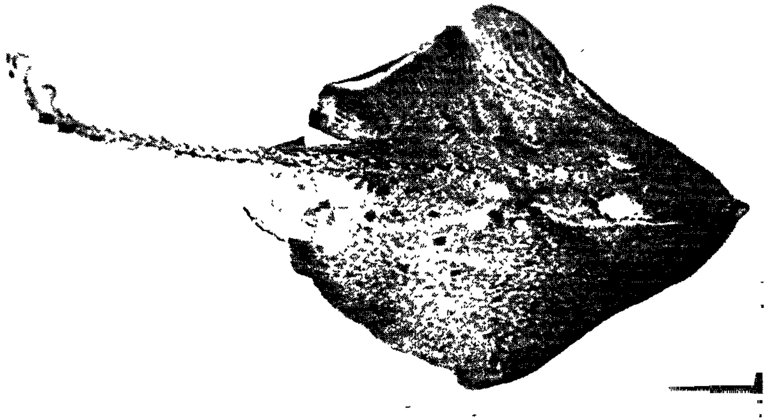
Insects that go through all four of these stages are said to have a complete metamorphosis. This does not apply to all insects. Some of the most primitive insects, such as the silverfish, have no metamorphosis at all: the young insect that hatches from the egg is like a small edition of the adult. In other insects the metamorphosis is incomplete. The young may resemble the adult in structure, but have no wings, these developing later. Here we cannot call the young insect a larva, and it is usually called a nymph: the cockroach is an example. In some insects, such as the dragonfly, which have young stages living in water, the young possess structures that fit them for aquatic life, and are not needed in the adult. The young dragonfly, for instance, has an extension to its lower lip, called the mask (Fig. 24), with which it catches its prey: this is lost in the adult insect. The young



7. The starfish (*Asterias*), seen from above.

8. The starfish (*Asterias*), seen from below. Note the ambulacral grooves running along the lower surface of each tentacle. The mouth is in the centre of the disc.

9. The sea urchin (*Echinus*).



10. The skate, seen from above.
11. The plaice, seen from above.
12. The plaice, seen from below.

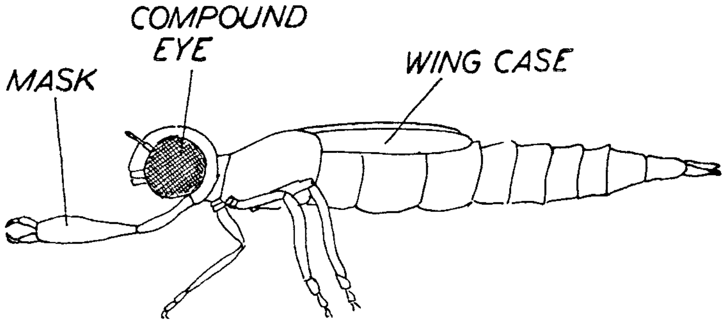


FIG. 24. LARVA OF THE DRAGONFLY, WITH MASK EXTENDED.

dragonfly can, therefore, correctly be called a larva, though it is commonly known as a nymph or naiad ("water-nymph").

Insects are of great economic importance. Many cause havoc to our crops, and others, like the mosquito, and the house fly, spread disease. It would be a great mistake, however, to regard all insects as enemies, for many of them, and especially the bees, are vitally necessary for the pollination of flowers, many of which can be pollinated in no other way.

The insects, besides being a large and important group of animals, are a fascinating object of study. It is impossible to do them anything like justice in a single chapter, and for more information about them I must recommend you to read some of the works mentioned in the "List of Recommended Books" (page 140).

The Arachnida

This group includes the spiders, scorpions and king-crabs, and also the mites and ticks.

Many people think a spider is an insect, but closer examination shows us that this is not so, for it has four pairs of legs instead of three. The possession of four pairs of legs is one of the main characteristics of the Arachnida: another is the way in which the head and thorax are fused together to form the cephalothorax —a point that they share with the Crustacea.

The web of the garden spider is a wonderful structure, and is built with amazing skill. The spider usually starts by forming a

triangle, the silk being produced by glands in the spider's body and guided into position by special appendages called spinnerets. The triangle makes a framework to support the net, which consists of a silken spiral held in place by diagonal straight threads (Fig. 25).

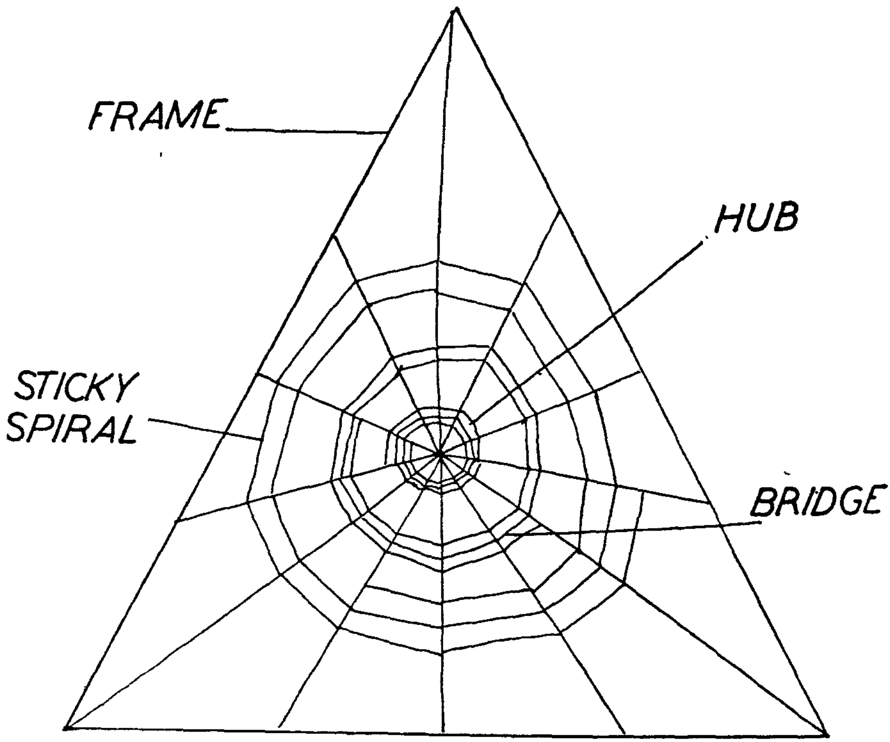


FIG. 25. WEB OF THE GARDEN SPIDER.

Contrary to popular belief, the spider does not leap upon its imprisoned prey and rend it in pieces. Instead, it injects saliva into the body of the victim. The saliva contains a powerful enzyme (an organic catalyst) that dissolves the body of the prey, leaving only the hard outer skeleton. The spider then feeds on the liquid remains.

The mating habits of spiders are very interesting. They often go through a complicated courtship ceremony, and in some spiders the male may be killed by his "wife" after mating.

The scorpions are large arachnids, varying from half an inch to eight inches in length. They often inhabit arid regions of the world, and are remarkable for the length of time that they can go without food or water. They are rapacious animals, feeding mainly on insects and spiders. Smaller victims are immediately torn to pieces with the pincers and eaten, while larger ones are usually first paralysed by the powerful sting that the scorpion carries in its tail.

The danger caused by scorpions has been much exaggerated in popular fiction. They sting only when molested, and, when disturbed, their first instinct is to run away and hide. The sting of a scorpion is unpleasant and can be dangerous, but it is not as deadly as has been suggested by writers of sensational books. It is also quite untrue that scorpions kill their young, or that they commit suicide by stinging themselves to death.

The king-crab (*Limulus*) is a curious animal that is common on the Atlantic shores of America (Plate 5). Seen from above, it is shaped like a horse-shoe, owing to the large, domed carapace that overlaps its body. It is a burrowing animal, living in the mud or sand of the sea bottom, mainly in from two to six fathoms of water. It feeds partly on shellfish, but its main diet consists of marine worms like *Nereis*, which it catches during its burrowing operations.

Limulus is a very ancient type of animal—a "living fossil" that has somehow persisted into modern times.

The mites and ticks (class Acarina) are small arachnids, many of which are blood-suckers and parasites of man and animals. Some of them are very important as carriers of disease: the tick *Ornithodorus moubata*, for instance, carries relapsing fever. The mite *Sarcoptes scabei* is parasitic on man, causing an intense itching of the skin known as scabies or, more simply, "the itch." It is very contagious, but not serious except for the discomfort it causes.

Finally, there are the Phalangida, small arachnids popularly known as "harvestmen" or "harvest spiders." They are active creatures, most often seen on the foliage of plants. They look rather like spiders, but can be distinguished by the absence of a "waist" between the cephalothorax and the abdomen.

Phalangida are sometimes found drinking the dewdrops that form on vegetation, and eating juicy plant matter, for they

appear to be thirsty animals. Their main diet is, however, flesh, and they savagely attack and eat insect larvae, small spiders and other tiny creatures. They are incorrigible cannibals, often killing and eating one another.

The Myriapoda

These are the centipedes and millepedes. They are small, terrestrial arthropods, living mainly in the soil, and they are easily recognized by their long, slender bodies and their many legs. A centipede does not have a hundred legs, or a millepede a thousand: the number is variable, depending on the particular species of animal.

Both centipedes and millepedes have very flexible bodies, and the millepedes in particular have a strong tendency to curl up. The centipedes are the more active of the two, for they are carnivorous, feeding on insects and insect larvae in the soil: in this way they help the farmer by reducing the number of insect pests. Millepedes, on the other hand, feed on the roots of plants, and can do a great deal of damage to crops.

Other Arthropoda

Besides the four main sub-phyla that I have described, there are various other groups that cannot be dealt with here, though they contain some very interesting animals. There is one very primitive arthropod, however, that should be mentioned: this is a strange creature called *Peripatus*.

This curious little animal is found only in warm countries,

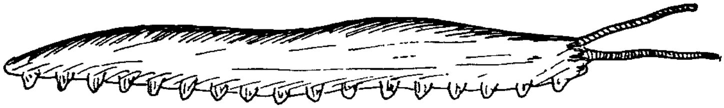


FIG. 26. *Peripatus*, A VERY PRIMITIVE ARTHROPOD.

where it lives in damp situations, usually hidden beneath stones, the bark of trees, etc. One reason for its retiring mode of life may be that it lacks the hard outer skeleton that is found in most arthropods.

On first sight, *Peripatus* might well be taken for a slug. It has

a long, soft body, with a pair of "feelers" stretching out in front (Fig. 26). It differs from a slug, however, in having a row of short cone-shaped appendages along each side of its body. Each appendage has a pair of claws at its tip.

We do not know exactly how *Peripatus* is related to the main groups of the Arthropoda, but it is clearly a very simple and primitive member of the Phylum. Like *Limulus*, the king-crab, *Peripatus* can fairly be called a "living fossil": a creature from very far-off days that has somehow managed to avoid becoming extinct with the passage of time.

CHAPTER IX

SNAILS AND SHELLFISH—PHYLUM MOLLUSCA

THE Phylum Mollusca includes the slugs and snails, the so-called "shellfish" such as oysters, mussels, whelks and winkles, the cuttle-fish, the octopuses, the squids, and many other strange and interesting creatures. Most of them are marine, but there are also various land forms, of which the snail is a familiar example.

The snail is a common animal in our gardens, where it does a great deal of damage by eating the foliage of plants. Besides the garden snail (*Helix aspersa*), there are various other species to be found in Britain: these include the large edible snail (*H. pomatia*), often to be seen on chalky soil, and a number of different water snails that live in streams and ditches. These are often kept in aquaria to clean the sides of the glass tanks, and we have already seen how the water snail *Limnaea* is responsible for spreading liver fluke among sheep on damp pastures (Chapter V).

The edible snail is sometimes said to have been introduced into this country by the Romans, but this is not true, for its shells have been found in deposits dating from long before Roman times.

The garden snail is also edible. It used to be an especially popular dish with glass-blowers, because they thought it improved their "wind" for glass-blowing. This was probably no more than a pleasant superstition.

If you look at a snail that has "come out of its shell" and is on the move, you can see that its body is roughly divided into three parts. In front there is the head. This is provided with a mouth, and two pairs of tentacles that are very sensitive to smell. The hinder pair of tentacles, which are placed on top of the head, are longer than the front pair, and at the tip of each of the long tentacles there may be an eye (Fig. 27), though in some molluscs the eyes are at the bases of the tentacles.

The eye of the snail is sensitive to light, and has a lens that enables the snail to see things, though its sight is not as acute as ours, as the eye is rather a simple structure compared with that of a vertebrate animal. The snail is, however, particularly quick at noticing movements. You can experiment with this by waving

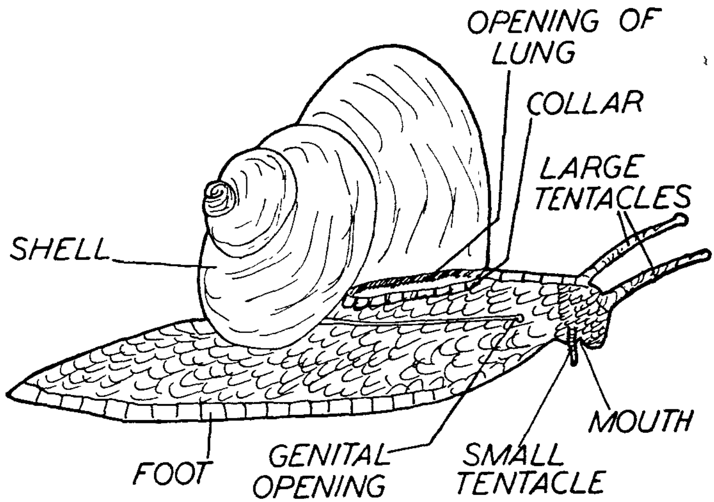


FIG. 27. THE GARDEN SNAIL.

a pencil in front of a snail that is on the move, and by varying the distance of the pencil from the snail you can get some idea of how close a moving object has to be before the snail notices it. You can generally tell if the snail has seen the pencil by watching for small movements of its tentacles.

Behind the head of the snail is the largest part of the body, which is called the foot. It is on the foot that the snail moves. The foot is very muscular, and if you watch a moving snail you can see that waves of muscular contraction pass along the foot. These contractions begin at the tail end of the foot, and run towards the head. You can see the movement particularly well if you can persuade the snail to crawl over a piece of glass, and look upwards at it from below.

The third part of the snail's body is the hump, which is on top of the foot. This is the part of the snail that stays in the shell,

even when the animal is moving about. Most of the vital organs of the snail are contained in the hump.

If you look just below the edge of the shell, you will see a fleshy fold running round it. This is called the collar, and it is really the edge of a sort of fleshy bag that forms a lining to the shell. This is the mantle. Between the mantle and the rest of the body is a cavity, known as the mantle cavity or lung, and it is by means of this that the snail breathes. Air enters the mantle cavity through a hole on the right side of the body, just beneath the shell.

The shell of the snail is hard, and is made up mainly of calcium carbonate (chalk). It is formed by the secretion of calcium carbonate and other materials by the outer surface of the mantle. The shell has three layers: an outer one, which is made up of an organic substance (concholin), and two inner layers which are mainly of calcium carbonate. The innermost layer is built up of very thin plates, and the light striking these gives rise to the colours we see when we look inside the shells of some kinds of snails, though these colours are seen much better in the shells of some of the snail's relatives, such as the oyster.

One of the first things that we notice about the shell of a snail is that it is coiled into a spiral. It is not only the shell that is coiled: the twisting applies also to the body of the snail, and this means that some parts have become twisted out of their normal positions. The anus or vent, through which undigested food is voided to the exterior, has come to lie on the right side of the body, just behind the opening into the lung, instead of being at the end of the body as it is in most animals.

Snails feed on leaves, as every gardener knows only too well. It cuts out pieces of leaf by means of a toothed tongue, called the radula, which cuts against a horny plate in the roof of the mouth.

We are all familiar with the silver track left by the snail as it crawls over the ground. This is due to a slimy substance that is produced by a gland called the pedal gland, just below the mouth. The slime helps to lubricate the ground on which the snail is moving.

The snail, like the earthworm, is hermaphrodite—both male and female at the same time. When mating, two snails approach one another, and, when they are close together, each shoots a dart, made of calcium carbonate, deep into the body of the other. Mating follows, each snail fertilizing the other.

The eggs are usually laid in July and August, in small holes in the ground, and the time needed for hatching is twenty-five days. The young snails emerge from the eggs with the beginnings of the shell already formed, and grow into adults.

Snails hibernate during the winter. In the autumn they stop feeding and hide under leaves or in holes in walls, often a number of them together. The body is completely drawn into the shell, and the opening of the shell is closed by a membrane (the epiphragm) made of calcium phosphate, leaving only a small hole through which air can enter the lung. Breathing becomes very slow, and the rate at which the heart beats drops from its normal ten to thirteen down to only four to six beats a minute. The snail may remain in this state for as long as six months.

The snails belong to the class Gasteropoda, which also includes the slugs. We commonly think of a slug as having no shell, but this is not always true. Some slugs, such as *Testacella*, have a small shell, rather like a cap. Others may have, in place of an external shell, an internal disc made of a horny substance, while others have no shell at all.

Most of the Gasteropoda are marine, and some of them are familiar objects of the sea shore. Most of us have, at some time or another, seen *Buccinum*, the whelk, exhibited on refreshment stalls at holiday resorts. The whelk lives mainly below the low-tide mark, reaching down to a depth of about 100 fathoms (a fathom is six feet). It is carnivorous, and is remarkable for having its mouth at the end of a proboscis which can be retracted into a sheath. The whelk feeds on both living and dead animals: its mouth has a strong radula (see page 72) used for rasping flesh, and this is strong enough to bore holes in the hard outer skeletons of crustaceans. The foot of the whelk is strong and muscular, and is used for grasping the prey.

The limpet (*Patella*) is adapted for living on exposed rocks between the high- and low-tide marks. Its shell is cone-shaped and streamlined, so that it is not easily torn loose by the waves, and is pressed tightly against the rocks by powerful muscles, which makes the limpet very difficult to move—hence the expression "clinging like a limpet."

The keyhole limpet (*Diadora*) gets its name from the hole at the top of its shell.

The periwinkle (*Littorina*) lives near the high-tide mark. It is

therefore uncovered by the tide most of the time, so that it is almost a terrestrial animal.

The sea hare (*Aplysia*) is a slug-like animal that may be seen browsing on seaweed between the tide marks. When young it remains below the low-tide mark, feeding on the red seaweeds that grow there, and its colour is red to match its background. As the animals grow older they feed in the intertidal zone, mainly on the green seaweeds such as the sea lettuce (*Ulva lactuca*), and their colour changes to green. *Aplysia* is called the sea hare on account of the two flaps that rise up from the sides of the foot and enable the animal to swim: these look rather like ears.

In the Gasteropoda the shell, if any, is in one piece. In the class Lamellibranchiata the shell is in two halves, as in the oyster and the mussel. The lamellibranchs have somewhat flattened bodies, and the mantle, which is large, forms two flaps, one on each side of the animal. Each of these mantle flaps forms its own half of the shell, and the two halves, when pressed together, enclose the body of the animal as if in a box. The shell is closed by powerful muscles: anyone who has prepared a live oyster for eating knows that quite a lot of force must be used to prize the two halves of the shell apart.

A lamellibranch does not keep its shell closed all the time, of course: if it did so, it would be completely cut off from the outside world, and it could not feed, breathe or get rid of its own waste products. Normally the shell is held partly open, and currents of water pass in and out, kept going by the movement of cilia on the gills and on the mantle. This circulation of water not only brings dissolved oxygen to the gills for respiration, but also carries the minute particles of food on which the animal subsists—an arrangement known as filter-feeding, as the food is filtered out of the water.

Most of the Lamellibranchiata are marine animals, but there are fresh water forms, of which the swan mussels (*Anodonta cygnea* and *A. anatina*) are the best known. These are not at all uncommon, but they tend to escape notice because they spend a great deal of their time buried in the mud in streams and large ponds. Their shells are dark grey, oval, and from four to six inches long.

The scallop (*Pecten*) is unusual among lamellibranchs in that the two halves of its shell are of unequal sizes, and in that it is

able to swim instead of being confined to crawling. It swims by quickly opening and closing the two halves of its shell, forcing water out between them.

The oyster (*Ostrea edulis*) has an interesting and unusual form of reproduction, for the same animal may function as male and female alternately. Oysters usually spawn most freely at full moon: in this they resemble some echinoderms (Chapter X).

Besides being delicious as food, oysters provide us with pearls. A pearl is formed when a small particle of foreign matter gets into the body of the oyster, setting up local irritation. A hard calcareous covering is formed round the source of irritation: this is the pearl. The pearls of commerce mainly come from tropical seas, but even our native British oysters sometimes form pearls, though these are seldom of any value.

We now come to the third of the five classes that make up the Phylum Mollusca. This is the class Cephalopoda, and it includes the octopuses, cuttlefish and squids. These are some of the most remarkable and interesting creatures in the whole of the Animal Kingdom.

The Cephalopoda differ in many ways from the rest of the Mollusca, and it is hard to believe that they belong to the same Phylum as the snail and the oyster. In the Cephalopoda there is a well-developed head, which bears a pair of very efficient eyes. In the head there is a concentration of nervous tissue, forming quite a complex brain that makes it possible for these animals to learn things from experience.

A remarkable feature of the cephalopods is the siphon. This is a tube, developed from the foot, through which water from the mantle cavity can be squirted with great force. This has the effect of driving the animal quickly through the water: it is, in fact, a form of jet propulsion, and it is highly effective. Over short distances, some of the cephalopods are probably the fastest things in the sea.

We have all heard of the tentacles of the octopus, eight in number, with suckers at their ends. The possession of tentacles is a characteristic feature of the Cephalopoda. It has been said that the tentacles are formed from the foot, but it is more likely that they are part of the head.

The earliest ancestors of the Cephalopoda had shells, consisting of many chambers and coiled in a spiral. As the animal grew, so

more chambers were added to the shell. The very common fossils known as ammonites (Fig 28) were built up in this way. Some living cephalopods are similarly constructed: *Nautilus*, found in

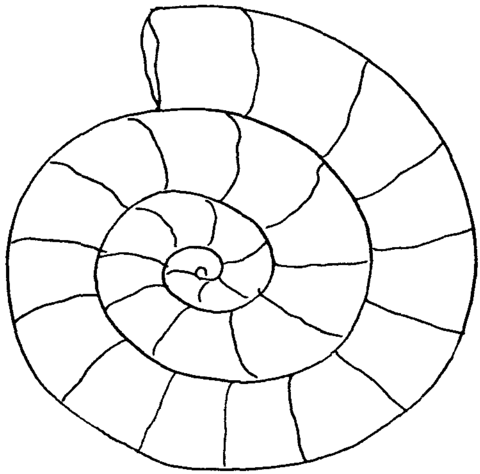


FIG. 28. FOSSILIZED SHELL OF AN AMMONITE, AN ANCIENT MOLLUSC.

tropical seas, is an example. *Spirula* is another tropical cephalopod with a shell (Fig. 29). Its home is in the West Indies, but its

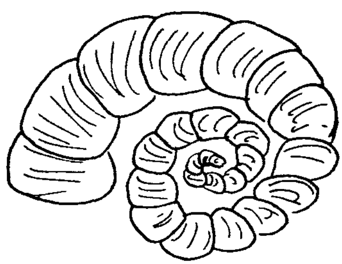


FIG. 29. SHELL OF *Spirula*.

shells are sometimes picked up on the coast of Ireland, having been carried there by the Gulf Stream.

In most living cephalopods there is either no shell at all, as in the octopus, or the shell is internal, as in the cuttlefish (*Sepia*).

The octopus (Fig. 30) is regarded by many people with con-

siderable horror, but this is mainly the fault of exaggerated accounts of giant octopuses that have appeared in stories from the time of Victor Hugo onwards. In fact, no octopus is longer than about ten feet, and as this includes its long tentacles the length of the actual body is much less. Octopuses that sink ships by

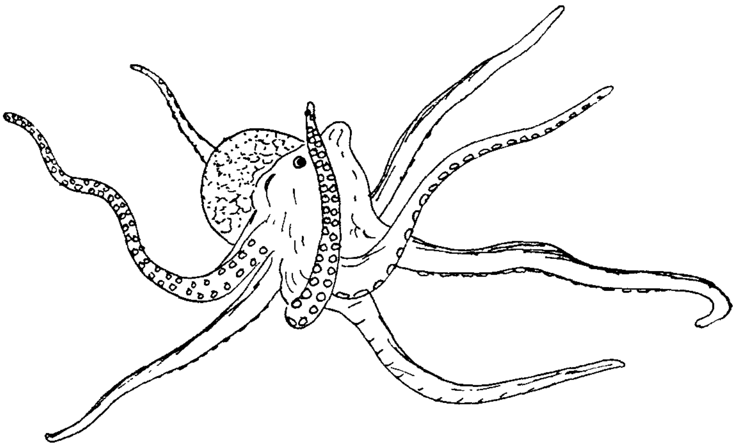


FIG. 30. THE COMMON OCTOPUS.

grasping them with their tentacles are pure fable, and can be classed with the giant sea serpent and the Loch Ness monster.

Two species of octopus are found on British shores: these are the lesser octopus (*Eledone cirrosa*) and the common octopus (*Octopus vulgaris*). The common octopus is the larger of the two, and may sometimes reach ten feet across its tentacles. It is really a native of the Mediterranean, but it sometimes visits the south coast of England, where it may be a great nuisance to crab and lobster fishermen, as it has a great appetite for crustacea.

The cuttlefish differ from the octopuses in having an extra pair of tentacles, longer than the others, making ten in all. A common example is *Sepia officinalis* (Plate 6). It also has a shell, which is inside the body instead of being on the outside.

Sepia lives on the sea bottom in shallow water. It feeds on shrimps, which it catches craftily by blowing jets of water into the sand in which the shrimps are buried. This exposes the shrimps, but the colour of their bodies matches the sand so well that the cuttlefish would probably not notice them if they had

enough sense to keep still. The natural instinct of the shrimp, however, is to cover itself with sand again: when it moves to do so, the cuttlefish sees it, and that is the end of the shrimp.

Sepia is remarkable for its ability to change colour quickly, an attribute that it shares with the octopus and the squid. The surface of the animal is covered with little spots of colour: these are really very small, elastic bags containing pigment. They are called chromatophores. By muscular action, any chromatophore can be expanded, so as to make a patch of colour. The chromatophores of *Sepia* are of three different colours: yellow, red and dark brown or black. If the chromatophores of a certain colour expand, while others contract, the animal will change its colour accordingly. Various mixtures of colours can be obtained. In this way, the animal is able to camouflage itself, whatever the colour of its background.

The common squid (*Loligo forbesi*) is found all round the coasts of Britain. Like *Sepia* it has ten tentacles, two of which are longer than the rest (Fig. 31). It is not a large animal,

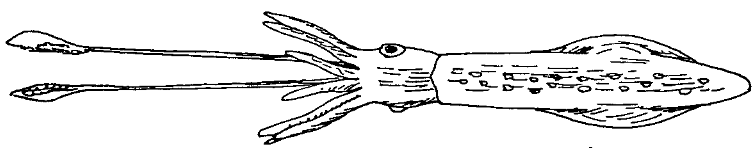


FIG. 31. *Loligo*, A COMMON SQUID.

usually measuring eight to twelve inches in length, though it may reach thirty inches on occasion. It seldom comes near the coast, but is often caught in the nets of trawlers fishing ten miles or so off shore. It lives on fish, crustaceans and even smaller squids.

The size of the squids, like that of the octopuses, has been much exaggerated, but some large specimens have been recorded. The largest are the giant squids, belonging to the genus *Architeuthis*, which have been known to reach a length of fifty feet. We must remember, however, that most of this length is accounted for by the two longer tentacles: the actual body of the animal would be less than a quarter of the total. This is a point for writers of science fiction to remember.

The other two classes of the Mollusca—the Amphineura and the Scaphopoda—are small groups. They are of considerable scientific interest, but we cannot deal with them here.

CHAPTER X

STARFISH AND SEA URCHINS—PHYLUM ECHINODERMATA

THE word echinoderm means "spiny skinned," and this is an apt description of the starfish and its allies. Their skins contain numerous calcareous fragments, known as ossicles, and in many the skin bears spines as well. They are all marine.

The most familiar of the group is the common starfish (*Asterias rubens*). This may be found on almost any beach, where it has been thrown up by the waves, usually dead, for its true home is below the low-tide mark. It is also an inhabitant of rock pools.

The body of the starfish is shaped like a five-pointed star, with five long tentacles, of approximately equal length, radiating from a central portion called the disc (Plates 7 and 8). Its colour is somewhat variable, from orange, through yellowish-buff to purplish. The surface of the body is soft, but just beneath the surface are many small calcareous rods, the ossicles, that form a strengthening meshwork. These can be felt if a finger is run over the skin of the animal.

In between the ossicles, the skin is raised into small, hollow pimples. These are the gills, by means of which the starfish absorbs dissolved oxygen from the sea water in which it lives. At the points where the ossicles join one another, blunt spines stick out from the skin. Around and between the spines we find large numbers of curious pincer-like structures, called pedicellariae. These are able to grip small objects that come into contact with the skin, and they are probably used by the animal in cleaning itself. They may also be organs of defence.

On the upper surface of the disc, placed at one side and between two of the tentacles, is a flat, round calcareous plate

called the madreporite. The surface of the madreporite is perforated with fine holes, through which water is drawn, by the waving movement of cilia, into a system of internal canals forming the water vascular system. Also on the upper surface of the disc, to one side of the madreporite, is the anus—the opening from the gut to the exterior.

The mouth is on the lower side of the disc, in the centre. From the mouth, a very short gullet or oesophagus leads upwards to the stomach. This in turn leads to the pyloric sac, with branches running into the tentacles, and then to a short tube, the rectum, which opens to the outside by the anus, on the upper side of the disc.

If you look at the underside of any one of the tentacles, you will see a groove running down most of its length (Plate 8). This is called the ambulacral groove, and the five ambulacral grooves meet at the mouth. Protruding from the grooves are the tube feet. These are small, cylindrical structures, and there are four rows of them, crowded together, along each of the ambulacral grooves. Each tube foot ends in a tiny sucker.

The tube feet are hollow, and they can be distended by hydrostatic pressure, water passing into them from the water vascular system. They are used by the animal in crawling over the sea bottom. By means of their suckers, the tube feet can get a grip on the surface on which the starfish is moving, thus enabling it to draw itself along, clumsily but effectively.

The tube feet are also used in feeding. In spite of its apparent inactivity, the starfish is a voracious animal. It may do considerable damage in oyster beds, for it has a particular taste for shellfish. In dealing with an oyster, or other bivalve mollusc, the starfish places two tentacles on one side of the shell and three on the other, gripping its prey firmly by the suckers on its tube feet, and forcibly prizing the two halves of the shell apart. Anyone who has tried to open an oyster with a knife will appreciate the strength needed to do this. Starfish feed extensively on mussels.

Having opened its oyster, the starfish consumes it in a most peculiar way. It has no means of biting its food into portions small enough to be taken in by its mouth, so it digests its meal outside its body by protruding its stomach through its mouth. The food is held firmly in the tentacles, which are brought close together, and gastric juices from the lining of the branches of

the pyloric sac digest the food. When the food is digested, the stomach is withdrawn, by the action of muscles, into its normal position.

Small animals may be taken in by the mouth in the normal way, but in the main the starfish feeds by this strange process of everting its stomach on to the food. Small pieces of shell and other undigested food particles are usually passed out by the mouth, and not by the anus as in most animals.

Living as it does in rocky places, the starfish is always in danger of having a tentacle trapped by a falling stone or caught in a crevice: it is also possible that a tentacle may be seized by an enemy. This is of little importance to the starfish, for it can shed a tentacle with great ease and grow another. This power of replacing a part of the body that has been lost is called regeneration, and it is very marked in the lower animals, becoming less as we rise in the evolutionary scale. An earthworm, if cut in half, can regenerate the missing half of its body, and some of the flatworms can do even better, a new animal growing from quite a small portion. You yourself can regenerate the damaged skin if you cut your finger, but you cannot grow a new finger. Man has progressed too far above the invertebrates for this to be possible.

The reproduction of the starfish takes place very simply. Male and female starfish do not differ from one another in appearance. The sex cells—sperms and eggs—are shed into the water, where the eggs are fertilized. After fertilization the egg does not grow directly into a young starfish. It first develops into a tiny larva which, unlike the parents, is bilaterally symmetrical—that is, it has left and right sides to its body. This larva is called a bipinnaria. After swimming for a time by means of cilia, it comes to rest and passes through a sedentary stage, after which it grows into a starfish.

Unlike the bipinnaria larva, the adult starfish is radially symmetrical—it can be cut into two similar halves in more than one way, and therefore cannot be said to have a right and a left side to its body. In this radial symmetry the starfish and most other echinoderms resemble the coelenterates (Chapter IV). Here, however, the resemblance ends, for the echinoderms are far more complex animals than the coelenterates, and belong to an altogether higher level of development.

There are several species of starfish to be found on our coasts, besides *Asterias rubens*. In the south and west you may find *Marthasterias glacialis*. This is a larger species, usually grey to mauve in colour, with spiny tentacles. The scarlet starfish (*Henricia sanguinolenta*), found especially on the east coast, is smaller and has thinner tentacles. Its colour, though typically red, is very variable. It can descend to a great depth in the sea. A somewhat rare species is the sun star (*Solaster papposus*), sometimes found on the coast in the west of England. This is a large species, which often has more than five tentacles; it may be purple, red or orange, often with white patches. Our smallest starfish is the starlet (*Asterina gibbosa*), which is usually no more than an inch in diameter, with a broad disc and very short tentacles. It is a rather dull brown in colour, and can easily be overlooked as it clings to the surface of a rock.

The starfish belong to the class of echinoderms called the Asteroidea, in which the tentacles that form the rays of the star are not very sharply marked off from the disc. Other features of the Asteroidea are the open ambulacral grooves on the lower sides of the tentacles, the tube feet with suckers at their tips, the presence in the tentacles of branches of the gut, and the presence of pedicellariae on the skin.

Somewhat resembling the starfish are the brittle stars, belonging to the class Ophiuroidea. These, like the starfish, have tentacles radiating from a central disc, but the tentacles are so sharply marked off from the disc that they resemble the spokes of a wheel rather than the rays of a star. The brittle stars also differ from the starfish in having no suckers on their tube feet, no branches of the gut in their tentacles, and no pedicellariae: another difference is that in the brittle stars the ambulacral groove is covered instead of being open as in the starfish.

Brittle stars are common in shallow water, but are not found on the shore as often as starfish. To find brittle stars, you should look in rock pools, or along the shore at low tide, near the edge of the sea. The commonest round British coasts is *Ophiopholis aculeata*.

The brittle stars share with the starfish the ability to regenerate a tentacle that has broken off. They shed their tentacles with great ease: so much so that it is sometimes difficult to pick up a living specimen without losing one or more tentacles. It is this

readiness to jettison a tentacle that gives these curious animals their name.

Some of the strangest of all marine animals are the sea urchins: these belong to the class Echinoidea. They are almost spherical. The ossicles form a series of tightly fitting plates, making a rigid foundation to the skin: the body of the animal thus resembles a spherical box. There are no tentacles. The surface of the body is divided into ten segments by double rows of tube feet. The skin bears long spines, giving the animal a bristly appearance; the commonest genus, *Echinus*, is named from a Greek word for the hedgehog, which is a reasonably apt description of the sea urchin (Plate 9).

The largest British sea urchin is *Echinus esculentus*, which may grow as big as a football. It is seldom found on the shore in the south, though specimens may be picked up at low tide in the north. The empty shells of sea urchins are, however, frequently washed up on the shore: these specimens have usually had their spines rubbed off by the buffeting of the waves. When alive, *E. esculentus* is a very beautiful object, with its purplish colouring and its long spines. Some parts of the body are edible.

Two small sea urchins are found quite often between the tide marks. These are *Psammechinus miliaris*, which is usually about two inches in diameter, and *Strongylocentrotus drobachiensis*, somewhat larger. Both are coloured green. *Paracentrotus lividus*, a common Mediterranean species, may be found on the Irish coast, and occasionally on the coasts of Devon and Cornwall. It has also been seen in the Hebrides.

The sea cucumbers, of the class Holothuroidea, are named from their resemblance to vegetable cucumbers. Their bodies are elongated and cylindrical, with the mouth at one end and the anus at the other. The tube feet run mainly in rows along the lower side of the body, enabling the animal to crawl, but some are modified to form a ring of tentacles round the mouth. These are sticky: food particles stick to them, and are then transferred to the mouth, almost as if the animal were licking its fingers after dipping them in a pot of jam.

Sea cucumbers are not well-known objects of our shores, partly because they are usually inconspicuous, for one species, *Cucumaria lactea*, is quite plentiful round British coasts. This is a small

species, usually about an inch long. *C. saxicola*, a rather larger species, is found in Devon and Cornwall.

In shallow tropical waters, sea cucumbers are plentiful, and often large. Some species are dried and eaten by the Chinese: a form of food known as trepang or *bêche-de-mer*, and regarded as a great delicacy.

The fifth and final class of the Echinodermata is the Crinoidea, containing the sea-lilies or feather stars. This is a primitive group, containing animals that are sessile for at least part of their lives. There is only one British species, *Antedon rosacea*, found in sheltered salt creeks and lochs.

The feather stars get their name from their tentacles, which are branched and feathery in appearance. *Antedon rosacea* has ten such tentacles arranged round the central disc. During the earlier part of its life it is sessile, remaining anchored to the bottom mud, below the low-tide mark, by twenty-five short stalks that spring from the lower side of the disc. As it gets older, however, it breaks free. Some crinoids remain permanently anchored: this is the case with *Rhizocrinus*, which is found in deep water.

CHAPTER XI

THE DAWN OF THE BACKBONE—PHYLUM CHORDATA

ALL the animals that I have talked about so far agree in one thing—none of them has a "backbone." They are known collectively as the Invertebrata, since they have no vertebrae—the bones of which the "backbone" of a vertebrate animal is composed.

We come now to the animals with backbones—the Vertebrata. These include the fishes, the amphibians such as the frogs, toads and newts, the reptiles, the birds and the mammals, as well as a few primitive vertebrates without jaws, such as the lamprey and the hag-fish.

There are, however, a few animals, such as the lancelet, the tunicates and the sea-squirts, that have no backbones but none the less seem to be related to the vertebrates. Because of this relationship, these animals are placed in the great Phylum Chordata, which includes the vertebrates as well.

The lancelet (*Branchiostoma lanceolatum* or *Amphioxus lanceolatus*) is a small animal, rather like a fish, found on the sea coast, living in shallow water where the bottom is sandy. It is between one and two inches long, with a slender body, pointed at both ends. It is usually found buried in the sand with only its mouth projecting, for, like the oyster, it is a filter-feeder (see page 74). When it comes out of the sand, which is usually at night, it can swim like a fish by a waving motion of its body, and when it is swimming it tends to keep turning to the right, so that it moves in circles.

The external structure of the lancelet is very simple. Its head is not clearly distinguishable from the rest of its body, except by the presence of the mouth, which is surrounded by a number of

fine tentacles—the oral cirri. The lancelet has no limbs, but there is a fin running along its back and another along its lower side; at the hinder end of the animal these fins become somewhat broader, forming the tail fin.

The thin skin of the lancelet is almost transparent, and through it we can see the muscles of the body wall. These are divided into about sixty muscular blocks, called myomeres, each shaped like a letter V with its point directed forwards. This division of the body muscles into blocks placed one behind the other is an example of segmentation, but the lancelet is not as completely segmented as the earthworm: the muscles show segmentation, and so do some of the internal organs, but not all of them.

From the mouth, a tube, called the alimentary canal, runs along inside the body, opening to the exterior by a hole, the anus, just in front of the tail. The front part of the alimentary canal, called the pharynx, is, as we shall see in a moment, concerned with breathing, while the rest has the work of digesting and absorbing the food.

The side walls of the pharynx are pierced by a large number of slits, which are placed obliquely so that their top ends are farther forward than their bases (Fig. 32). These are the gill slits. Water taken in by the mouth passes out through the gill slits, the water current being maintained by the waving action of cilia, and as it does so, dissolved oxygen is removed by blood vessels on the gill bars that separate the gill slits. The oxygen is used by the animal in respiration.

The current of water through the gill slits, maintained by the action of the ciliated cells in the pharynx, not only brings oxygen, but also food. The lancelet is a filter-feeder. Minute organic particles in the water are entangled in sticky mucus produced by cells in the floor of the pharynx, and the movement of cilia carries them first upwards and then backwards, along the alimentary canal. In its feeding habits, therefore, we can compare the lancelet with molluscs such as the mussel and the oyster.

The water that passes through the gill slits does not reach the outside directly: it passes first into a chamber called the atrium. This is formed by two flaps from the body wall, which join below the body to form a cavity. From the atrium the water finally leaves by an opening called the atriopore, in front of the anus.

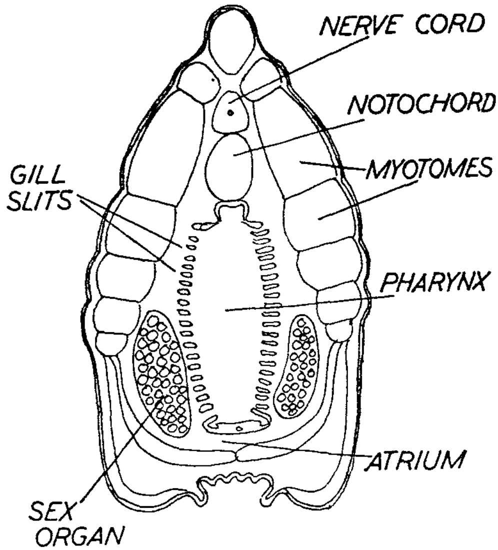


FIG. 32. SECTION THROUGH THE BODY OF *Branchiostoma*, THE LANCELET, NEAR THE "HEAD" END.

The lancelet has no bones and no skeleton. Running along its back, however, is an elastic rod called the notochord, which to some extent takes the place of a "backbone." Above the notochord runs the nerve chord, the main nerve of the body, corresponding with the spinal chord that runs inside the backbone of a vertebrate animal. In the vertebrates there is no notochord as such in the adult animal, except in certain fishes such as the dogfish and the sharks, but a notochord is formed in the embryos (unhatched or unborn young) of all vertebrates. This is one point that indicates the relationship of the lancelet and other primitive chordates with the Vertebrata.

The reproduction of the lancelet is a very simple process. The sex organs or gonads are found in the body wall: twenty-six of them on each side of the animal. The sex cells—sperms in the male animal and eggs in the female—are set free in the atrium and pass out through the atriopore. The eggs are fertilized by the sperms in the water.

The lancelet is a very primitive "poor relation" of the Verte-

brata. We include it in the phylum Chordata for the following reasons:

1. It has a notochord.
2. Its nerve cord is hollow and is dorsal in position—i.e., it runs along the back (top) of the animal (in the earthworm and in the Arthropoda the nerve cord is ventral—i.e., it runs along the front (bottom) of the animal).
3. It has gill clefts that open from the pharynx to the exterior.

These three characteristics are shared by all the Chordata and are not found in any of the other phyla in the Animal Kingdom.

We cannot include the lancelet in the vertebrata—the sub-phylum to which nearly all the chordates belong—because it has no "backbone" and no bony skeleton. We therefore place the lancelet in a sub-phylum called the Cephalocordata.

Besides the lancelet, there are certain other primitive chordates that are excluded from the Vertebrata. The sub-phylum Hemichordata includes a worm-like marine animal called *Balanoglossus*. This creature has gill slits and a dorsal nerve cord: it also probably has a notochord, but this is not quite certain.

The sub-phylum Urochordata contains some curious marine animals known as sea-squirts. An example is *Ciona*, which is quite common in the sea round Britain.

Ciona has a sack-like body, which is enclosed in a kind of loose jacket called the tunic. At the top of the animal is the mouth, through which water is drawn into a very large pharynx. The walls of the pharynx are perforated by very many small slits, which lead into another cavity, the atrium. The slits are well provided with cilia, the waving motion of which produces a strong current of water, which passes in at the mouth, through the slits into the atrium, and then out again by another opening at the top of the animal, the atriopore. The slits in the wall of the pharynx of *Ciona* are considered to be homologous with—i.e., of the same nature as—the gill slits of fishes (see Chapter XII). The current of water carries food particles with it: *Ciona* is a filter feeder.

Seen by itself, *Ciona* may well be taken for an invertebrate. It is only when its full life history is taken into account that its chordate nature becomes clear. The larva of *Ciona* is a little creature, rather like a tadpole. It has an oval "head"—really the

body, for it contains all the internal organs—and a long tail. In the tail there is a notochord, giving it support: this alone is sufficient to justify classifying *Ciona* with the Chordata.

Ciona is a sessile animal (see page 28), living on the sea bottom: it is also solitary. Some of its relatives are colonial. There are also free-swimming forms, such as the barrel-shaped *Dololium*. This curious creature practises a form of jet-propulsion: water is drawn it at the mouth, at the front of the animal, and expelled through the atriopore at the back, thus pushing the little creature along.

Oikopletura, a small animal that lives in a gelatinous "house" and looks rather like a *Ciona* tadpole, is sometimes an important food for fish, especially flatfish such as the plaice.

The fourth sub-phylum of the Chordata, and by far the biggest, is the sub-phylum Vertebrata. This includes all the animals with backbones: the fishes, amphibians (frogs, toads and newts), reptiles, birds and mammals. It also includes a few strange, primitive vertebrates without jaws, such as the lamprey and the hag-fish.

Although the vertebrata are but one sub-phylum of the Animal Kingdom, they are so numerous and so important that they form one of the two main groups into which animals are commonly divided. It is with the Vertebrata that the remainder of this book will be concerned.

CHAPTER XII

ANIMALS WITH BACKBONES—SUBPHYLUM VERTEBRATA

IN the last chapter we looked at some primitive chordate animals in which there is an elastic rod, called the notochord, running down the body, just below the main nerve cord. None of these animals, however, possess a bony skeleton and, in particular, none of them has a "backbone." We now come to the great section of the Animal Kingdom in which the body is supported by a skeleton, made usually of bone but sometimes of a softer material called cartilage. Running down the back of the animal is the "backbone" or vertebral column, to which the other parts of the skeleton are attached. The vertebral column is made up of a number of bones, called vertebrae, placed one behind another.

At the front end of the vertebral column is the skull—a hollow box that contains and protects the brain, and also carries the jaws. The fore and hind limbs are attached to the vertebral column by a number of bones that form the limb girdles—the shoulder and hip.

The vertebral column is not solid. Each vertebra is in the form of a ring (Fig. 33). The lower part of the vertebra is called the centrum: above this, making the ring, is the neural arch. When the vertebrae are fitted together, one behind another, the neural arches form a tube, housing the spinal cord or nerve cord, which joins the back of the brain. The brain and spinal cord together make up the central nervous system, and from them nerves run to the various parts of the body, controlling their activities.

The skeleton of a vertebrate animal not only supports the body, but also forms a rigid framework to which the body muscles are attached.

A notable feature of the Vertebrata is the great development of nervous tissue in the head, forming the brain. In the invertebrates, the brain is represented, if at all, by small groups of nerve cells called the cerebral ganglia. Very few invertebrates have anything that could justly be called a brain, though the cephalo-

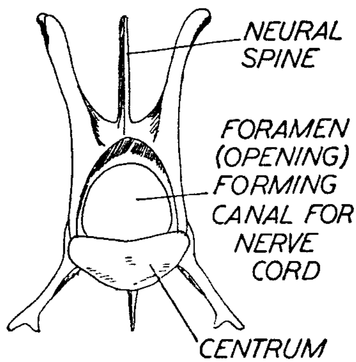


FIG. 33. A VERTEBRA OF THE RABBIT (LUMBAR REGION), SEEN FROM IN FRONT.

pod mulluscs such as the octopus come very near to it. In their mental development, the higher vertebrates are a long way ahead of their nearest invertebrate rivals.

The vertebrate skeleton is an efficient arrangement, and allows for great variety of structure in animals suited to very different modes of life. The vertebrate limbs, for instance, can form paddles for swimming (seals and penguins), legs for swift running (horses, antelopes, etc.), stout pillars for supporting great weight (legs of the elephant), wings for flying (birds), and tools for performing very delicate manipulations (hand and arm of man). All these very different kinds of limbs are built on the same general plan. No other group of animals shows such great adaptability as the vertebrates. This efficient organization, assisted by their greater brain power, has made them dominant over all others.

The vertebrates are not only the most efficiently designed animals: some of them are also the biggest. All the land invertebrates are relatively small. An invertebrate such as the giant squid can get along all right in the ocean, for the water helps to support its weight. On land it would be helpless. The vertebrate

skeleton has solved the problem of size for land animals that no longer have the support of water—though even for vertebrates there is a limit.

We sometimes read in story books of gigantic insects, six feet long and a yard high, threatening to displace man from the earth. These could not exist outside so-called science fiction. The rigid outside skeleton of an insect, which cannot grow with the body, and the insect's peculiar method of breathing by means of air tubes that carry air to its tissues, set an absolute limit to the size that it can reach. A cockroach as big as a cow would be utterly impossible.

There is, however, a limit to the size that even a vertebrate can attain, especially if it lives on land. This is because as the size of an animal increases, its volume, and hence its weight, increases faster. The giants of the fairy tales could never have existed—unless their size has been very much exaggerated by fable! Their bones would not have been strong enough to support their great weight.

The strength of a bone depends on its area of cross-section. Assume, for simplicity, that the cross-section of the bone is a circle: we all know that the area of a circle is in proportion to the *square* of its radius. The volume of a sphere, however, is in proportion to the *cube* of its radius. Of course, an animal is not a sphere, but it is near enough for this argument to apply approximately. Imagine a giant ten times the height of a normal man. The bones of his legs would be about 100 times as strong as ours ($10^2 = 100$), but he would weigh about 1,000 times as much as we do ($10^3 = 1{,}000$). If he tried to stand up, his legs would break under his own weight.

Next time you go to the zoo, look at the legs of the elephant. Notice how thick they are—they have to be.

Another feature that has probably helped the vertebrates a great deal in their rise to dominance is the efficiency of their hearts, which provides them with an effective blood circulation. This is important. The blood not only carries dissolved food material from one part of the body to another: it carries the oxygen that the cells of the body need for their respiration, and also removes from the cells the carbon dioxide that is produced, as a waste product, by the respiratory process. If muscles are to work efficiently, they must have a good oxygen supply.

In the vertebrates, the heart has at least two main chambers—four in the higher vertebrates. The blood contains millions of tiny cells—the red corpuscles—that have the red pigment called haemoglobin. This is what gives the blood its red colour. Haemoglobin has the useful property of easily combining with oxygen from the air, and as easily giving it up again. When the blood is brought by the circulation to the lungs—or gills, as the case may be—the haemoglobin combines with oxygen, forming a loose compound called oxy-haemoglobin. The blood then travels round the body, coming into close contact with all the body cells, the constant circulation being maintained by the pumping of the heart. As the blood circulates, the oxy-haemoglobin of the red corpuscles gives up its oxygen to the cells, once more becoming haemoglobin. In this way, the oxygen supply of the cells is kept up.

As the cells use the oxygen in their respiration, they give off carbon dioxide. This dissolves in the liquid part of the blood—the plasma—and is brought back to the lungs or gills, where the blood gets rid of it.

The process of respiration in cells is rather like slow burning. When a fire burns, the coal is combining with oxygen in the air, setting free energy as it does so. The energy appears as heat. When coal (carbon) combines with oxygen in this way, carbon dioxide gas is formed. We say that the coal is oxidized. In the cells of the body, food material containing carbon is oxidized by oxygen taken from the blood: carbon dioxide is produced, together with energy that is used by the animal for the working of its muscles, and for other vital processes. The more active the animal, the more oxygen it needs.

The simplest and most primitive vertebrates are known as the Agnatha—a word that means "without jaws." These include the lampreys and the hag-fishes. They are small, rather eel-like animals, and are mainly marine, though the lampreys have fresh-water larvae. They differ from other vertebrates in having no jaws. Their mouths are adapted for sucking, and they feed on fishes: the hag-fishes, in particular, burrow into the bodies of fishes by entering through the mouths of their victims, which are always fishes that are dead or dying. Hag-fish can be a great nuisance to fishermen, as they may attack fishes after they have

been caught on lines or in nets, and before they have been hauled out of the water.

The remainder of the Vertebrata are known as Gnathostomata. Their skulls are provided with true jaws. They include all the familiar vertebrates—the fishes, amphibians, reptiles, birds and mammals.

CHAPTER XIII

THE FISHES

THE fishes are a very large group of the Animal Kingdom, and a very ancient one. They are aquatic animals, breathing by means of gills that extract the oxygen dissolved in the water in which they live; there are, however, a few fishes (the Dipnoi or lung fishes) that can breathe air, at least to some extent. The outer covering of a fish includes scales of various kinds, and the limbs of a fish are fins. Besides the pectoral and pelvic fins that are the actual limbs, other fins are also normally present, including a caudal or tail fin.

There are so many different kinds of fish that no single example can be taken as typical of them all. One that is often used by zoologists as an introduction to fishes in general is the dogfish—a kind of small shark that is not uncommon round the coasts of Britain. There are several species: that most commonly found round the south of England is the lesser spotted dogfish or rough hound (*Scyliorhinus caniculus* or *Scyllium canicula*).

Dogfish are carnivorous, and they get their name from their habit of hunting in packs, like wild dogs. Moreover, they hunt, like dogs, by smell. Their diet is extremely varied: they will eat shellfish, crabs, lobsters, smaller fishes, and many other things, dead or alive. They are greedy creatures, and sometimes annoy fishermen by taking bait off the line. Dogfish can be eaten, and are often found in fish-and-chip shops under the flattering name "rock salmon."

A fair-sized dogfish is about two feet long, with a slender body that tapers from the head towards the tail: this streamlined shape allows it to slip easily through the water. The head is blunt, with a wide mouth that is placed, as in all sharks, on the lower side of the head, beneath the snout. A pair of nostrils lie just in front of

the mouth, to which they are connected by grooves. On the sides of the head, above and a little behind the mouth, are the eyes (Fig. 34).

Along the lower side of the head are five vertical slits. These are the gill slits, through which water comes out after passing

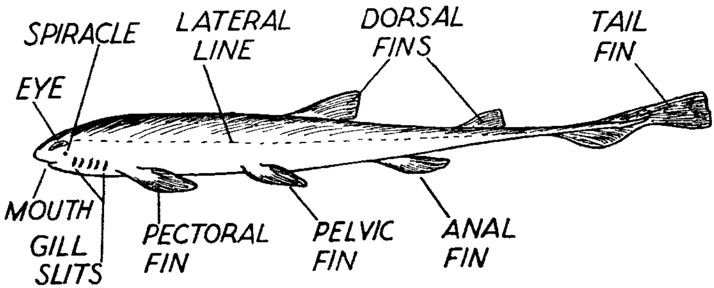


FIG. 34. THE COMMON DOGFISH, *Scyliorhinus caniculus*.

over the gills. Just in front of the gill slits is another, smaller, opening, called the spiracle.

The body of the spotted dogfish is coloured dark brownish-grey on top, becoming paler down the sides, and is almost white underneath; the colouring is not even, but arranged in spots or patches. The dark back and light belly help to make the dogfish less conspicuous, especially as it lives mainly near the sea bottom: this is an advantage, since it hides the animal both from its enemies and its prey.

The limbs of the dogfish are fins. The two front limbs form the pectoral fins, placed just behind the gill slits, and the two hind limbs are the pelvic fins, farther back. In the male dogfish, the two pelvic fins are joined together underneath the body, along their inner edges, and from each of them a rod-shaped structure, called the clasper, points backwards. The claspers are used, during mating, to assist in passing the male sex cells (sperms) into the body of the female, for in the dogfish fertilization takes place internally, and not externally as in most fishes.

Besides the paired pectoral and pelvic fins, the dogfish has two dorsal fins on its back, placed one behind the other, a single ventral or anal fin underneath, and a caudal fin running round the end of the tail. The caudal or tail fin has two lobes, of which the upper one is the larger.

If you run your hand over the skin of a dogfish, from tail to head, it feels very rough. This is because there are, embedded in the skin, many small spines. These are the scales of the dogfish, and they are very different from the scales of most fishes. Each scale consists of a small plate, bearing a sharp spine that is directed backwards—hence the rough feeling when you stroke the skin from the tail towards the head. Scales of this kind are called placoid scales, and they are characteristic of the dogfish and its allies.

If we cut a placoid scale in half vertically, we find that the spine has much the same structure as a tooth. It is made up chiefly of a bone-like substance called dentine—the material that teeth are made of—covered with a hard substance called enamel, similar to the enamel that covers teeth (Fig. 35). In the centre is

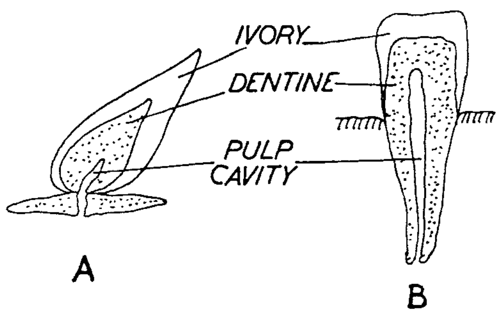


FIG. 35. COMPARISON BETWEEN A PLACOID SCALE OF THE DOGFISH (A) AND A MAMMALIAN TOOTH (B).

a small pulp cavity containing living tissue: in this again the placoid scale is like a tooth.

The teeth of the dogfish are like placoid scales, except that they are larger. It is very likely that the teeth of vertebrate animals in general have evolved, through the ages, from placoid scales.

The streamlined body of the dogfish shows no obvious division into head, body and tail when seen from the outside, for these parts merge smoothly into one another. The tail is that part of the body that lies behind the vent or anus, the opening through which undigested food passes out from the gut. About one-third of the length of the body is included in the tail, which is built of solid muscle and contains no internal cavity.

The body muscles of the dogfish, like those of the lancelet (Chapter XI) are arranged in blocks (myomeres), but this arrangement is not obvious in the head and certain other parts. In its muscles, therefore, we can say that the dogfish shows segmentation. Anyone who has eaten a fish will have noticed the segmented arrangement of the muscles.

Like all vertebrate animals, the dogfish has a skeleton, but this is not made of bone, as in most fishes, but of a softer material called cartilage. A cartilaginous skeleton is found in all the Elasmobranchii—the class to which the dogfish, the sharks and the skate belong. At one time it was thought that a skeleton of cartilage was a primitive feature, and that the dogfish and its allies stood lower in the scheme of evolution than the fishes with bones. We now have reason to believe that this idea is wrong: it is quitely likely that the dogfish and other elasmobranchs have descended from bony fishes, the bones having been replaced by cartilage in the course of millions of years of evolution.

We can divide the skeleton of the dogfish into two main parts—the axial skeleton and the appendicular skeleton. This applies to all vertebrate animals. The axial skeleton consists of the skull and the vertebral column or "backbone," while in the appendicular skeleton are included the limbs, and the limb girdles to which the limbs are attached.

The skull of the dogfish, like the rest of the skeleton, is made of cartilage. The upper part forms the cranium or brain box, a hollow case that encloses the brain. Beneath this we find the jaws, and behind them are the hoop-like bars of cartilage that lie between the gill slits. The back of the skull is attached to the front end of the vertebral column, and has an opening, the foramen magnum, through which the spinal cord—the main nerve of the body—runs into the brain.

The vertebral column of the dogfish is made up of about 130 separate vertebrae. The lower part of each vertebra is called the centrum: in most vertebrates this is solid, but in the dogfish it is perforated, the perforations of each successive vertebra forming a canal running right along the vertebral column. Inside this canal we find the notochord (Chapter XI). This is unusual: although all vertebrates have a notochord when they are embryos, it usually disappears in the adult. In the dogfish and other elasmobranchs, however, the notochord remains.

Rising above the centre of the vertebrae are the neural arches that enclose the spinal cord. This is more than a nerve: it is a collection of nerves, running out of the back of the brain and right down the body. From the spinal cord, spinal nerves are given off, between the vertebrae, to the various organs. The brain and spinal cord together form the central nervous system.

The paired fins of the dogfish correspond with the arms and legs of man, or the fore and hind limbs of land animals. They are supported by cartilages, as well as by horny fin rays, and they are attached to cartilaginous limb girdles—the pectoral girdle in front and the pelvic girdle behind. In most vertebrates the limb girdles are attached to the vertebral column, but in the dogfish they are not.

Closely related to the dogfish are the sharks, which include some of the largest of the fishes (we must remember that the whales are not fishes, but mammals). The large man-eating sharks are mainly found in tropical seas: *Carcharodon*, one of the fiercest, may reach a length of thirty-feet. The largest living shark, however, is the basking shark (*Cetorhinus*), which may exceed thirty-five feet. It is a harmless creature that has given up attacking large prey and taken to straining small organisms out of the sea water by means of special combs on its gills. This is a form of filter feeding, and its effectiveness is demonstrated by the great size that *Cetorhinus* can attain.

Some of the fossil sharks that lived in days gone by were far bigger than any of the sharks we know today. It is thought that some of the fossil sharks related to *Carcharodon* may have reached a length of ninety feet. If they were as savage as *Carcharodon*, they must have been fearsome brutes indeed.

The skates and rays are relatives of the dogfish that have taken to living entirely on the sea bottom where they feed mainly on invertebrates of various kinds. This mode of life has led to certain changes in their bodies. Instead of being torpedo-shaped, they are flattened, and their eyes have moved from the sides of their heads to the upper surface (Plate 10). Their method of swimming is different, too: instead of driving themselves through the water by muscular movements of their tails, they swim by waves of movement passing along their fins. They do not draw water in through the mouth for respiration, but take it in through the spiracle (see page 96).

The skates and rays are placed in a group called the Hypotremata. Some of them have unusual methods of defending themselves from their enemies. In the sting rays, for instance, the tail forms a lash that can be used as a defensive weapon, and the dorsal fin has been modified to form a poison spine. In the electric ray (Torpedo) there is an electric organ, formed from muscle, which can inflict a nasty shock on any animal that touches certain parts of the ray's body.

So far we have only discussed the fishes with skeletons made of cartilage (class Elasmobranchii). In most fishes, the skeleton is of bone, as in other vertebrates. The bony fishes make up the class Actinopterygii.

The bony fishes are a large group, and they are world-wide in their distribution, inhabiting a great variety of different kinds of places. It is not surprising, therefore, that they vary a great deal from one another both in their size and in the form of their bodies. Altogether, more than 20,000 different species of bony fishes are known.

As individuals, the bony fishes are very numerous indeed. About 3,000 million herrings are caught every year in the Atlantic. Strung together, nose to tail, they would reach as far as the moon, and half way back again. And yet these must represent but a fraction of the total number of herrings in the Atlantic. Such numbers are almost impossible to imagine.

The bony fishes differ in a number of ways from the elasmobranchs, apart from the presence of bone in their skeletons. A typical bony fish, such as the trout or the herring, has a body that is short and deep compared with the dogfish, and narrow when measured from side to side. The mouth is placed at the extreme end of the head, instead of being underneath as in the dogfish (Plates 11 and 12). The tail fin is symmetrical in shape, whereas that of the dogfish is larger above than below. If we look at the skeleton of a bony fish, however, we still find that the extreme tip of the vertebral column bends upwards, towards the upper lobe of the tail fin.

One of the most obvious differences that we notice between a bony fish and the dogfish is that in the bony fish the gill slits are no longer visible from the outside. They are covered by a flap called the gill cover or operculum. When the fish takes in water through its mouth, the gill covers lie flat against the sides of the

body. The mouth then closes, and, as the water is driven over the gills, the edges of the gill covers move away from the body, allowing the water to escape.

The scales of a bony fish are different from those of the dogfish. They consist of flat, bony plates, lying just under the skin, and they do not have the tooth-like projections that make the skin of the dogfish so rough. The scales overlap, rather like the tiles of a roof, each scale overlapping the one behind. They are made of bone, and, as they grow, the bone is deposited in concentric rings. The formation of the growth rings is due to the fact that growth is not constant throughout the year: it is fastest in the spring and summer, and during the winter it almost stops. We can thus tell the age of a fish by counting the rings on its scales, just as we can tell the age of a tree, after it is felled, by counting the growth rings on the stump.

A feature of bony fishes that is not found in the elasmobranchs is the presence in the body of an air bladder or "swim bladder." This is a large bag, filled with oxygen, that lies inside the body cavity, above the gut. The oxygen in the bladder is secreted by glands in the wall of the bladder itself. The action of the oxygen glands can be controlled by the nervous system of the fish, so that the amount of oxygen produced can be varied according to circumstances.

The air bladder is probably concerned with adjusting the buoyancy of the fish according to its depth in the water. If more oxygen is secreted into the bladder, causing it to expand, the fish will become more buoyant, and so rise nearer to the surface: conversely, if some of the oxygen in the bladder is absorbed, the buoyancy of the fish decreases, and it sinks. The principle of this arrangement is rather like that of the hydrostatic tanks of a submarine.

It seems likely that the air bladder first evolved, not as a hydrostatic organ, but as an accessory means of respiration, enabling the fish to breathe air to some extent. Many fishes are able to do this, and some can live out of water at least for a time. The ability of an eel to make its way through damp grass is well known, but a much more striking instance is that of the Indian climbing perch (*Anabas*), which lives mainly on land, where it can move by means of its fins. This remarkable fish has air chambers situated just above its gills, and even when in water,

it comes to the surface to breathe by gulping air: if held under water it will eventually drown.

The habit of breathing air is particularly well developed in the small group known as the lung fishes (class Choanichthyes). Of these, there are, as far as we know, only four living representatives: *Neoceratodus* (Queensland, Australia), *Protopterus* (Africa), *Lepidosiren* (South America) and *Latimeria* (South Atlantic).

The first three of these belong to the group of lung fishes called the Dipnoi. These remarkable creatures show many points of difference from other fishes. One is the absence of vertebrae in the skeleton: instead of a backbone, there is a notochord.

In the Dipnoi, the air bladder is able to function as a lung, at least to some extent, enabling these fishes to breathe air. In this way, they are able to survive in mud, or in water where the concentration of oxygen is too low for normal gill breathing to be effective.

Latimeria is a particularly interesting fish because it belongs to a group called the coelacanths, thought to have been extinct for many millions of years. A specimen was, however, taken from the South Atlantic off the coast of Africa, during the course of fishing, and finally arrived at a museum at East London, where it was recognized as a "living fossil." It is unlikely that *Latimeria* is itself an air-breather, for there does not appear to be any internal connexion between the mouth and the nostril.

The senses possessed by fishes have long been a subject of argument, especially among anglers. It is difficult to get exact information about this subject, for fishes inhabit a very different world from ours. All are agreed, however, that the sense organs of fishes are well developed.

We have already seen that the dogfish hunts its prey by smell. The bony fishes also have a sense of smell, though we are uncertain whether it is a good one or not. A bony fish has a pair of nostrils on the surface of its head, but there is no communication between the cavity of the nose and the mouth, as there is in our own noses. There is no doubt, however, that the nose of a bony fish enables it to find food at a distance.

The eye of a fish is built on the same general plan as our own, but there are differences in detail, especially in the mechanism by which the eye is focused. Some fish are able to vary the size

of the opening in the iris, through which light enters the eye, according to the brightness of illumination, but others do not have this power.

The ear of a bony fish is enclosed in the skull. It consists of the inner ear only: there is no ear-drum to receive vibrations from the outside world. Sounds—which to a fish are, of course, vibrations in the water, and not vibrations in the air, as they are to us—must affect the ear of the fish through the skull bones. We must remember, however, that water is more efficient in conducting sound than air, because of its greater density.

It is sometimes said that fishes have no sense of hearing, but this is certainly not true of all fish, even if it is true of any. It has been shown by experiment that some fishes can not only hear, but can also distinguish between sounds of different pitch.

The sense of taste is well developed in bony fishes. We get our sense of taste by means of tiny swellings called taste buds, which are found on the tongue and on the walls of the mouth. In fishes the taste buds are not confined to the tongue and mouth: they are distributed over various parts of the body, and some are even found on the tail. We can therefore truthfully say that a fish tastes things all over its body!

Fishes possess another sense that is not found in land animals. This is provided by what are called the lateral line organs. These are found in a series of pits, which lie along two lines, one on each side of the body. The lateral line organs are found in the elasmobranchs such as the dogfish, and they are even better developed in the bony fishes.

The exact function of the lateral line sense organs has been much disputed. It appears to be an important one, for the lateral line is found in all fishes, and also in the aquatic larvae of amphibians. From the results of experiments, it appears that the lateral line organs are sensitive to the movement of water against them, and it is suggested that they enable fishes to detect vibrations in the water.

CHAPTER XIV

FROGS, TOADS AND NEWTS—CLASS AMPHIBIA

It seems reasonably certain that the Amphibia were the first vertebrates to colonize the land. This initial invasion from the sea probably occurred during the Devonian period of geological history, something like 275 million years ago. We do not, of course, know just how it occurred, but we cannot doubt that the original ancestors of the Amphibia were fishes that took to the land. Probably these were lung fishes that lived in ponds and small lakes: we can imagine them at first crawling from one piece of inland water to another, gradually becoming more venturesome in their journeys, spending more and more time ashore, until, by a slow process of bodily change, they developed into the beginnings of the Amphibia.

Our fossil records show that there were amphibians living in Devonian times. These primitive members of the class were unlike our present-day frogs, toads and newts: many of them were distinctly fish-like in their general form, and not so well adapted to terrestrial life as the Amphibia that we know today. These fossil Amphibia are placed in a sub-class called the Stegocephalia—a mixed group containing animals that in many cases were probably not very closely related to one another.

During Devonian times, there was a tendency in many places for the sea to recede and the land to dry up. Fishes inhabiting inland pools and lakes found themselves in danger of being left high and dry. Any fish that was able to live out of water would have had a distinct advantage over its fellows: it would have had a better chance of surviving under these precarious conditions and, surviving, of leaving offspring behind it to carry on the breed.

With the land drying up, the lungfish must have been well placed to survive where other fish were doomed. Their swim

bladders were already modified to enable them to breathe air, at least to some extent, and they could already leave the water without gasping to a rapid death. Here, then, was ready material from which amphibians could evolve.

The change from aquatic to terrestrial life must have brought many problems, some of which the Amphibia have only partly solved. The body must support its own weight, without the help of water. Gills must be given up in favour of lungs, so that gaseous oxygen from the air can be breathed, in place of oxygen dissolved in water. A skin must be developed capable of preventing the animal from becoming dried up by the evaporation of water from its body. Last, but far from least, limbs must be developed if the animal is to move about on land.

We do not know exactly how the limb of a land animal developed from a fin. Probably the lungfish that gave rise to the ancestral stock of the Amphibia had fins that were lobed, like paddles. At first, these fins would move backwards and forwards, helping the animal to slide over the ground. Later, the body would be raised off the ground, the weight being taken by the fins. This would be followed by the development of knee and ankle joints, making the limb more flexible and efficient.

The word "amphibious" means "living both on land and in water," and this is true of the class Amphibia. They have many of the characteristics of typical land animals: they breathe air, they have walking legs instead of fins, and so on. At the same time, most of them are perfectly at home in the water—and—a very important point—they go back to the water to breed.

This last point is well illustrated by the life history of the common frog (*Rana temporaria*). At breeding time, the male and female frogs make for the water. The eggs are laid, usually in shallow water, and as they are laid the male frog fertilizes them. The eggs hatch into tadpoles, and these are entirely aquatic: they are fish-like in form, with tails but no limbs, and they breathe by means of gills. Only when the tadpole is about two months old do the lungs begin to function: we then find that the tadpole is beginning to come to the surface of the water to take gulps of air.

Even when the tadpole has become an adult frog, complete independence of water is not achieved. A frog can only live under moist conditions—either in water, or amongst damp vegetation.

A frog placed in a perfectly dry situation will die: it is not adapted to living completely without external water. For one thing, a frog breathes partly through its skin, which is kept moist by mucus secreted by various glands. If the skin were to dry up, this form of respiration could not take place. When a frog is at rest, the skin plays a bigger part in its respiration than the lungs, and when the frog hibernates it respires entirely through its skin.

Present-day Amphibia can be divided into three sub-classes. The sub-class Urodela contains the newts and salamanders. These are Amphibia which have still got a tail: they have not lost the long, fish-like body of their early ancestors. The Anura is the sub-class to which the frogs and toads belong. Here the tail has been lost, and the body has taken on a form more suggestive of a terrestrial animal. The Anura have adopted jumping as their most important method of locomotion when on land, and the long, muscular legs that make them such good jumpers are equally useful when swimming. Finally, there is the sub-class Apoda. These are limbless, blind and worm-like, living in the tropics and burrowing in the ground.

There is a fourth sub-class in the Amphibia: this is the Stegocephalia, which I have already mentioned. This group consists entirely of fossils: as far as we know there are no stegocephalians alive today.

The frogs are both the commonest and the most successful of the Amphibia. There are nearly three thousand different species of frogs scattered about the world, but only one of these, the common frog (*Rana temporaria*), is native to Britain, though two other species have been introduced.

Everyone is familiar with the appearance of the common frog, with its squat, neckless body, humped back, wide mouth and bulging eyes. The front legs are short and relatively feeble: they are used in crawling on land, and for breaking the animal's fall when it leaps. The hind legs are long and powerful, with webbed feet that assist the frog in swimming.

The ears of the frog have no external lobes (pinnae), but we can see the eardrums outlined on the sides of the head. The internal ear cavity connects with the nose and mouth, just as ours does.

The skin of the frog is moist and slimy, and is remarkable for the way in which it changes colour according to conditions out-

side. This colour change is brought about by the expansion and contraction of pigment cells in the skin of the frog (Fig. 36); when they expand, the area covered by the dark pigment they contain becomes greater, and the colour of the skin darkens. If

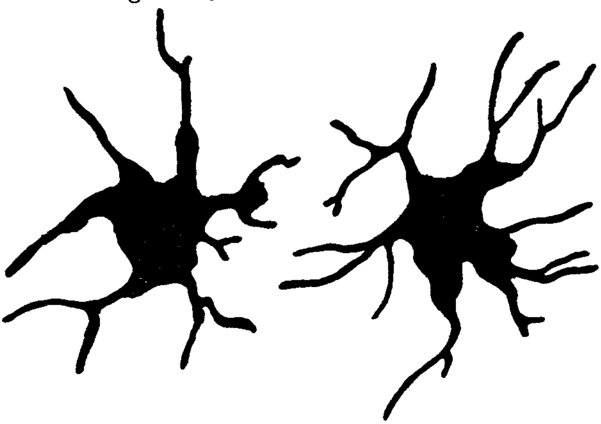


FIG. 36. PIGMENT CELLS IN THE SKIN OF A FROG.

the pigment cells contract, the pigment covers a smaller area, and the colour of the skin lightens. If the frog's surroundings are dark, cold or wet, the pigment cells tend to expand; conversely, they contract under conditions of light, heat or dryness.

If you watch a living frog you will notice, beneath its throat, a constant pulsation of the skin. This is a breathing movement. A frog does not breathe in the same way as a mammal, by alternately expanding and contracting its chest. Instead, it pumps air into its lungs by raising the floor of its mouth. The floor of the mouth is then lowered, and the natural elasticity of the lungs causes them to contract, driving the air out.

In mammals, air is sucked into the lungs, instead of being forced in. When the chest expands the lungs expand with it, thus sucking air in : when the chest contracts, the opposite takes place. We can express the difference between the frog and the mammal in engineering terms by saying that the frog has a force pump and the mammal a suction pump.

In the frog the skin, as we have seen, plays a considerable part in respiration. The lining of the mouth, which is very well supplied with blood vessels, also assists.

The diet of the common frog consists of small animals of

various kinds, and it does not seem to be very fussy about what it eats. It will take worms, slugs, small snails, insects, spiders, caterpillars and other insect larvae, and anything else that is small and living. By destroying harmful insects and their larvae the frog does good work for the farmer, and we should regard it as a friend.

The frog has a curious method of catching its prey. Its tongue, unlike ours, is attached to the front of its mouth, and when at rest it normally points backwards into the throat. When a frog catches an insect or other small animal, it flicks its tongue out of its mouth. In the roof of the frog's mouth are glands that secrete a sticky substance: as the tongue flicks out, it picks up some of this on its forked tip, so that the prey sticks to it and can be drawn into the mouth.

There are no teeth on the lower jaw of the frog, but the upper jaw is armed with numerous pointed teeth, which slope backwards, thus helping in holding the living prey. There are also some "vomerine teeth" on the roof of the mouth. The frog does not chew its food, but swallows it whole.

The life history of the common frog, with its larval stage, the tadpole, is almost too well known to need description. Frogs normally breed in March, and at this time of year large numbers of them congregate in the neighbourhood of ponds. The male frog mounts on the back of the female, clasping her round the body with his fore limbs, and the paired frogs may remain in this embrace for several days, until the eggs are laid. The female lays her eggs in the pond, and as she does so the male sheds sperms over them, fertilizing them. The eggs are covered with a slimy coating, which swells in contact with the water, forming the familiar jelly that surrounds the frog spawn, the small black dots in the jelly being the actual eggs. When she has laid all her eggs, the female croaks, and this seems to be a sign for the male to let go.

During the breeding season, the male frog develops a pronounced swelling on the first finger of each hand (the frog has no thumb). This is called the nuptial pad (Fig. 37), and it helps the frog to grasp the female during egg laying. The presence of the nuptial pad is a convenient way of recognizing male from female frogs during the breeding season.

The egg hatches into a tadpole, which at first is entirely fish-like, with no limbs and a strong tail with which it swims. When

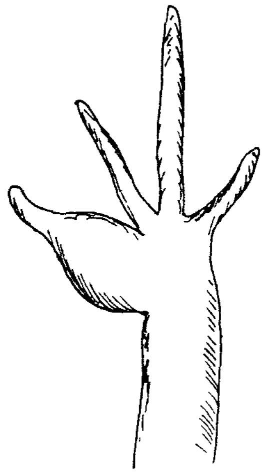


FIG. 37. RIGHT HAND OF A MALE FROG DURING THE BREEDING SEASON, SHOWING THE NUPTIAL PAD.

first hatched it has no mouth, but this soon develops, and the little creature begins to feed, at first on plant matter, but later on the flesh of any dead animals that it may come across, including other tadpoles or even dead frogs. Tadpoles are highly efficient scavengers.

At first, the young tadpole breathes by means of external gills —branched structures, sticking out on each side of the head. Later these disappear and are replaced by internal gills, like those of a fish. In due course, the lungs begin to operate, and at this stage the tadpole begins to gulp air from the surface of the water. At the same time, the legs are beginning to develop: the hind limbs are the first to be visible for, though the forelegs develop at the same time, they are hidden by the gill covers during the early stages of their growth. The tail is gradually absorbed and disappears, the tadpole becoming more and more frog-like, and at last the metamorphosis (change from the larval form into the adult) is complete.

The common frog is the species universally distributed over Britain, but two other species have been introduced from the Continent, and are sometimes found. These are the edible frog (*Rana esculanta*) and the marsh frog (*R. ridibunda*).

The edible frog is somewhat larger than the common frog, and may reach a length of about four inches. It is thought to have been originally introduced into this country about a hundred years ago, and is found in certain places in Middlesex, Surrey and

Kent, as well as at Woburn Park in Bedfordshire. It is seldom found more than a few yards from water, and, unlike the common frog, it will feed in water as well as on land. It breeds later in the year than the common frog, and, as its eggs do not float, its spawn is less often noticed.

The marsh frog was first introduced to this country in 1935, from Hungary. The original specimens were put into Romney Marsh, where it has bred freely and spread very rapidly. It is even larger than the edible frog, and varies very much in its colour. It is a voracious beast, and has even been known to devour small mice.

A number of species of frogs have taken to living in trees: *Hyla* is one of the best known. These tree-frogs have pads on their toes that help them to climb.

Toads are similar to frogs. Our British species can be distinguished from frogs by their dry, warty skins. They live in drier places than the frogs, and are less at home in the water. We have two British species: the natterjack toad (*Bufo calamita*) and the common toad (*Bufo bufo*).

There are many popular fables about toads, most of which are quite untrue. One that has a foundation in fact, however, is that they are poisonous. A fluid is secreted by glands in the skin that is distasteful, and possibly injurious, to animals that attempt to seize toads in their mouths. A more powerful fluid is also produced by glands in the neck of the toad. This production of venom is, however, a purely defensive measure: a toad is a harmless creature, and can be handled with perfect safety. Toads are intelligent, as amphibians go, and make good pets, as they will feed quite happily in captivity.

Toads, like frogs, return to the water to breed. The eggs of toads are laid in "ropes," like strings of beads, instead of in masses like those of the frog.

The newts and salamanders make up the sub-class Urodela. On the whole, they have undergone less specialization for life on land than have the Anura (frogs and toads). There is less difference between the adult and the larva in the newts and salamanders than there is in the frogs, and often the adult animal retains characters that are suited to life in water rather than on land.

Some of the Urodela are fully terrestrial: the spotted salamander (*Salamandra maculosa*), for instance, is viviparous (brings

forth its young alive). Others are completely aquatic, such as the North American mud-puppy (*Necturus*) and the American hell bender (*Cryptobranchus*).

We have three British newts: the crested newt (*Triturus cristatus*), the common newt (*T. vulgaris*) and the palmate newt (*T. helveticus*). All three are semi-aquatic. The largest is the crested newt—so called because in the breeding season the male has a crest running from the back of the head down the body. A large specimen may be as much as six inches long. The common newt is seldom longer than four inches, and the palmate newt is smaller still.

Newts, like frogs and toads, are flesh eating. Their food consists of aquatic insects, water fleas and any other creatures small enough for them to deal with. They will also eat tadpoles, both of frogs and of other newts.

Newts are found in ponds all over Britain and Ireland, though the three species vary a little in their distribution. The crested newt, for instance, is not found at all in Ireland, and in Wales and the west of Scotland the palmate newt is the commonest of the three.

The life history of a newt is in general similar to that of a frog: it breeds in water, and the young stage is a tadpole. The behaviour of newts during breeding is, however, quite different from that of frogs. There is quite a complicated courtship ceremony, after which the male newt deposits his sperm in a small packet at the bottom of the pond, where they are picked up by the female. The eggs of a newt are not laid in a mass, like those of frogs, but each egg is laid separately and wrapped up by the female in a piece taken from the leaf of a water plant. For this operation she uses her hind legs.

The tadpoles of a newt are very similar to those of a frog, and, like frog tadpoles, they are flesh-eating. A point of difference between newt and frog tadpoles is that, as newt tadpoles pass through the stages of their development into adults, the hind legs appear before the front ones.

The third sub-class of the Amphibia is called the Apoda, which means "without feet." These curious animals are found only in the tropics, where they burrow, like earthworms, in the ground. They are without legs, and blind, the eyes being replaced by sensory tentacles. Their eggs are laid on land.

CHAPTER XV

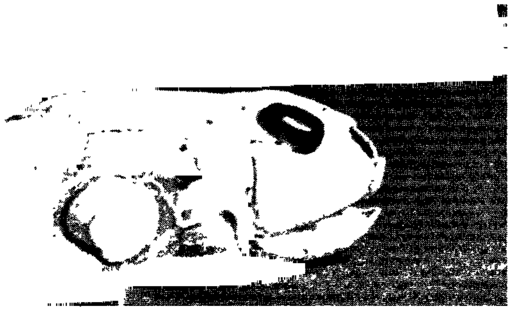
SNAKES, LIZARDS, CROCODILES AND TURTLES—CLASS REPTILIA

THE Amphibia appear to have been the first vertebrate animals to become adapted for life on land, but even in the modern amphibians the adaptation is, in most cases, far from complete. If we look back for a moment at the frog, and remember its moist skin, which must not be allowed to dry up, its habit of returning to the water to breed, and its aquatic tadpole stage, it is clear that the frog is only in part a land animal.

With the reptiles it is different. Here we have, at last, vertebrates that can live wholly on land, without returning to the water at all, though many reptiles, such as the crocodiles, are, in fact, aquatic. The skin of the reptile is dry, and usually covered with an armour of scales. A reptile is in no danger of drying up if it forsakes the protection of moist vegetation. More important still, reptiles breathe air throughout their lives; they do not use gills at all, even when newly hatched from the egg. The reptiles have finally deserted the water and taken to the land—even if some of them have gone back to the water again.

Reptiles are cold-blooded animals: the temperature of their blood, and hence of their bodies, varies with that of the surrounding air—or water, if the reptile is aquatic. In this they resemble the fishes and amphibians, and differ from the birds and mammals. This means that the reptiles can only lead active lives when their surroundings are warm: when the weather is cold they become sluggish, and in the winter they must hibernate. That is one reason why we find a much greater variety of reptilian life in tropical and subtropical countries than in Britain. In England we have only six native reptiles—three snakes and three lizards, if we count the slow-worm as a lizard, which is what it really is.

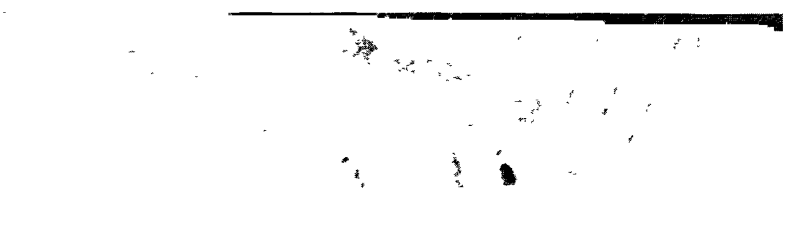
In this country, the most widespread lizard is the common



13. THE SKULL OF A TURTLE.

14. THE SKULL OF A CROCODILE.

15. SKELETON OF THE WING OF A PIGEON, SHOWING THE INSERTION OF THE FEATHERS.



16. HUMBOLDT'S PENGUIN (CHESSINGTON ZOO, SURREY). NOTE THE WINGS MODIFIED FOR SWIMMING.

17. A GROUP OF ROSY FLAMINGOS (CHESSINGTON ZOO, SURREY). AT REST, THIS BIRD STANDS ON ONE LEG, WITH ITS LONG NECK CURLED ROUND AND ITS HEAD THRUST INTO ITS WING.

18. THE BEAVER (CHESSINGTON ZOO, SURREY). NOTE THE FLAT TAIL, JUST VISIBLE UNDER THE WATER.

lizard (*Lacerta vivipara*), which occurs throughout Britain, including Ireland. The sand lizard (*L. agilis*) is found only in the south of England, especially in Surrey, Hampshire and Dorset.

The common lizard lives in a hole, either in an old wall or in a bank, usually in a fairly dry place. It is very variable in colour: dark brown, yellowish or even greenish on its back and sides, and lighter coloured underneath—red or orange in the male, and orange or yellow in the female, usually with black spots mingling with the colour.

The common lizard is flesh-eating and catches insects of various kinds, spiders, earthworms and anything else small enough for it to manage. Its movements when hunting are very quick, and it also relies mainly on its speed to escape from enemies, though if cornered it will fight. In common with other lizards, it has another interesting escape mechanism. If grasped by the tail, it suddenly stiffens the tail muscles. This has the effect of rupturing the tail vertebrae, so that the tail comes off. The piece of tail left behind will continue to move for a time after it is shed, and this may serve to capture the attention of the enemy while the lizard gets away.

The common lizard breeds in late spring. As with most reptiles, the eggs are laid on land, and this means that they must have some kind of covering to support them and keep them from drying up. Instead of being naked, therefore, like the eggs of a frog, the eggs of the lizard have shells. The shell is put on to the egg before it is laid, which means that the eggs must be fertilized while still within the body of the female, before they have received their shells. During mating, therefore, the male lizard inserts the sperms into the body of the female, where fertilization takes place. The eggs then pass down a tube called the oviduct, leading to the exterior, and as they do so, glands on the walls of the oviduct secrete the shells around them.

The Latin word *vivipara* in the scientific name of the common lizard means that the young are born alive—there is no period of waiting for the eggs to hatch. In this species the eggs normally hatch as they are laid, so that the young lizards appear immediately. The young resemble the adults, except in size: there is no larval stage corresponding with the tadpole of the frog.

The sand lizard is somewhat larger than the common lizard, and is much less common. It is usually found on sandy heaths,

such as those of Surrey and Hampshire. It feeds in the same way as the common lizard. Its young are not born alive: it lays eggs in a hole in the ground, covering them with loose sand and leaving them to hatch in the heat of the sun. The time needed for hatching varies from two to three months. The young lizard has an "egg tooth" on the end of its nose, which it uses to break the egg shell when it is ready to come out of the egg.

The slow-worm (*Anguis fragilis*) is a lizard without legs. It is a snake-like creature, but it betrays itself as a lizard by the form of its teeth, and by having eyelids, which are absent in snakes. It is found throughout England, Wales and Scotland, but not in Ireland. Its food consists of small animals: insect larvae, spiders, earthworms, and it is particularly fond of small slugs. Like the common lizard it bears its young alive.

The lizards and snakes belong to the order Squamata, the lizards occupying the suborder Lacertilia. They show great variation in size, appearance and habit, and include some remarkable creatures. Most of them are flesh-eating; a few are vegetarians.

The iguanas are some of the largest of the living lizards, *Iguana* itself, a native of South and Central America, often attaining a length of six feet. A relation of the iguanas is the horned toad, found in the deserts of western United States and Mexico. This animal, often mentioned in "Western" stories, burrows in the sand, and is the only one of the iguana group to produce living young.

The chameleons are climbing lizards found in Africa and India. They show some interesting adaptations for living in trees. Their hands and feet are so arranged that they can grasp branches as they climb, and their tails are also adapted for grasping. They eat insects, which they catch by flicking out their very long tongues, the ends of which are club-shaped and sticky.

The chameleons, as is well known, are remarkable for their changes of colour, which are brought about by the alteration in size of pigment cells in the skin. At night, a chameleon is usually cream-coloured, with yellow patches here and there. In the daytime the colour will change, according to circumstances, through grey-green to dark brown, with patches and spots of other colours. These colour changes are probably protective, causing the animal to merge with its background; it is also likely that they help the animal in hunting insects, making it less conspic-

uous to its victim, and they may also assist in regulating the animal's temperature to some extent, since different colours both radiate and absorb heat to different extents.

The snakes belong to the suborder Ophidia. They probably arose originally from lizards that had taken to burrowing underground: this would explain the absence of legs. Snakes show considerable differences from lizards in the form of many of their organs, and especially their eyes. It has been suggested that these may have been lost by the underground ancestors of the snakes, and developed again, with a different structure, when the snakes left the subterranean world and returned to the surface. This may also explain the very poor sense of hearing possessed by snakes: the popular expression "deaf as an adder" has a sound biological foundation. It is quite likely that the sense of hearing was lost when the ancestors of the snakes went underground.

A remarkable feature of the snakes, and especially those that possess poison fangs, is the way in which the jaw is modified to allow them to swallow large objects. In venomous snakes, the prey is paralysed by the poisoned bite, and then swallowed whole. The lower jaw does not articulate firmly with the skull as it does in most vertebrates, and the two halves of the lower jaw are able to separate from one another to some extent. It is thus possible for the snake actually to swallow animals with a diameter greater than its own head—a seemingly impossible feat.

We have three native British snakes: the grass snake (*Tropidonotus natrix*), the adder or viper (*Vipera berus*) and the smooth snake (*Coronella austriaca*). Of these, the adder is the only one that is poisonous. Although the bite of an adder is seldom fatal, it is highly unpleasant, and anyone who is bitten should be given hospital treatment at once. An adder can usually be recognized by the dark zig-zag line running down its back, but its colour is highly variable and an exact description that will fit all adders is impossible. Snakes found in the wild state should not be handled until their identity is known for certain.

The pythons and boa constrictors are primitive snakes. They are not poisonous, and they kill their prey by winding themselves round it and crushing it to death. The South American anaconda belongs to the same group.

The cobra (*Naja tripudians*) is a highly poisonous snake that is able, when roused, to dilate its neck, the swelling forming what is

often called the "hood." This is probably a warning mechanism, intended to scare off an enemy. The American rattlesnake has a rattle at the end of its tail, formed from the remains of former skins cast off during the course of growth. The rattlesnake is found in the grass of prairies, and the rattle is probably a warning to keep large animals such as bison from treading on the snake.

The tortoises and turtles belong to the order Chelonia. These curious reptiles have short, broad bodies which are enclosed in a box made of bony plates, into which the head and legs can be drawn. There is no fundamental distinction between a tortoise and a turtle: the name tortoise is generally used for those that live on land or in fresh water, while marine species are commonly known as turtles. Some of the turtles are very large, the leathery turtle (*Sphargis*) reaching a length of more than six feet. The edible turtle is *Chelone mydas*, a fair-sized animal, often a yard long.

We come now to the crocodiles and alligators, of the order Crocodilia. These are aquatic reptiles, and their heads show some interesting adaptations to their habitat. The nostrils are on the very end of the snout, and the air taken in has to pass through a long bony passage to the back of the throat (Plate 14). A crocodile can lie wholly submerged, except for its nostrils, waiting for its prey, and still breathe. The crocodile can keep its mouth open under water without choking, for the passage leading from its throat to its lungs is covered by a flap on the back of its tongue. It can therefore seize its prey even with its head below the surface. If you try to bite a bun under water in a swimming bath, you will find that the crocodile is one up on you here.

The commonest of the crocodiles is *Crocodilus*, which is found in four continents—Africa, Central America, Asia and Australasia, including Australia itself. *Alligator* comes only from Central and South America, with the exception of one species from China. *Caiman*, a close relative of *Alligator*, also belongs to Central and South America. *Gavialis* comes from India, where it is known as the ghavial: it is one of the "long-nosed" crocodiles, and lives on fish.

Strange though some of our present-day reptiles are, they are eclipsed completely by some of the gigantic reptiles that lived in past geological ages, and which included the largest animals that have ever lived on land. These reached their peak during Jurassic times, more than 200 million years ago.

Most of these gigantic reptiles, now known to us only as fossils, are collectively referred to as dinosaurs, though the name has no particular zoological meaning, as they included at least two separate lines of evolution.

Some of these monsters of the past were flesh-eaters, and they must have been fearsome creatures indeed. *Tyrannosaurus rex*, for instance, the largest of the flesh-eating dinosaurs, was fifty feet long and twenty feet high. It walked on its hind legs, like a kangaroo, balanced by its massive tail: its forelegs were relatively small, though armed with formidable claws.

The record for size, however, must go to some of the plant-eating dinosaurs: *Brontosaurus* and *Diplodocus*, for instance, were both up to eighty feet long, with a small lizard's head on a long neck, a thick, heavy body and a very long tail. The weight of such an animal must have been around fifty tons. Probably they spent a great deal of time in water, for such a weight would be very hard to support on land. Some of these creatures are known to have been aquatic: *Plesiosaurus*, for instance, with a body not unlike *Brontosaurus*, had limbs modified to form flippers for swimming. It has been suggested that the famous "Loch Ness Monster" may have been a plesiosaur that somehow managed to hang on from Jurassic times, but the suggestion is not taken very seriously in scientific circles.

People sometimes ask why these great reptiles, having succeeded in reaching such a remarkable size, should have failed to survive. There are many possible answers to this, two of which stand out particularly clearly. One is that such great size is not necessarily an advantage. These animals were too unwieldy, especially for life on land. The other is that, in spite of the great size of their bodies, their brains were relatively small. If you examine a fossilized skull of an eighty-foot *Brontosaurus*, you will find, from the capacity of the cranium or brain box, that this monumental animal had a brain no bigger than that of a kitten. This need not mean that these animals were stupid, but a certain lack of balance is suggested by such a small brain in such a large body. When the more intelligent and better adapted mammals arrived on the evolutionary scene, these great reptiles could not compete with them. The mammals were also probably helped in the competition by worsening climatic and physical conditions, with which they could cope better than the reptiles.

CHAPTER XVI

BIRDS—CLASS AVES

THERE are few animals more fascinating to watch and study than the birds. Not only do they show great beauty of form and movement, but their habits also are a subject of absorbing interest to many thousands of naturalists, both professional and amateur. It is in the study of birds, even more than the insects, that the amateur biologist really comes into his own.

The most outstanding feature of the birds as a group is the way in which they have overcome the many difficulties that attend life in the air. In their complete mastery of flight they stand apart from all other animals, for even the insects cannot match them as aviators. Many of the characteristic features of birds have been evolved, directly or indirectly, in response to the demands of flight.

Birds are the only animals that bear feathers, and without feathers their highly developed powers of flight could never have been attained.

Feathers are of various kinds. The largest are the quill feathers found in the wings and tail. Next come the contour feathers that cover the body of the bird, after which we have the very small feathers—the filoplumes that are found among the contour feathers, and the down feathers that we see particularly on young birds.

The wing of a bird corresponds with the arm of a mammal, such as a man, and we can even trace the same bones in it, though there are differences in their relative sizes and importance, because of the adaptation of the limb to flight.

The skeleton of the wing of a bird is shown in Plate 15. The main flight feathers are firmly embedded in the bones, as they need to be able to withstand the strain that is placed upon them

when the bird is flying. These feathers are known as remiges (singular, remex), and they are further named after the bones that carry them—e.g., metacarpal quills, etc. The remiges are accompanied by smaller quill feathers called coverts or tectrices, which cover the remiges. The feathers of the upper arm, or humarals, come into this group.

The structure of a quill feather is shown in Fig. 38. It consists

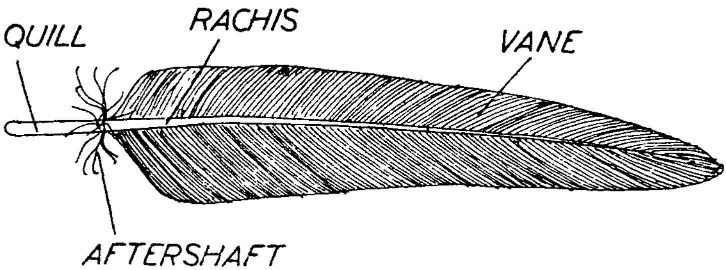


FIG. 38. A QUILL FEATHER.

of a shaft or rachis to which the flat part or vane (vexillum) of the feather is attached. Below the vane the rachis passes into the hollow quill. At the junction of rachis and quill there is often a small tuft called the aftershaft.

The vane itself is made up of a large number of barbs. These are really a series of flattened parallel plates, attached to the rachis and arranged with their flattened sides perpendicular to the flat plane of the feather (Fig. 39). The barbs are fringed with small projections called barbules, and the barbules themselves bear tiny hooks or barbicels that interlock with the barbicels on the adjoining barbules. In this way the barbs are held together and prevented from opening apart, so that air does not easily pass through the vane of the feather.

This is why, when the barbs of a feather have been disarranged, it is not easy to fit them together again. It is also why order may often be restored by pulling the feather through the fingers from the quill to the tip, for this helps to rearrange the barbules and their barbicels.

The coverts are built on the same sort of general plan as the remiges, but are smaller. The contour feathers are smaller and simpler still, with poorly developed barbules.

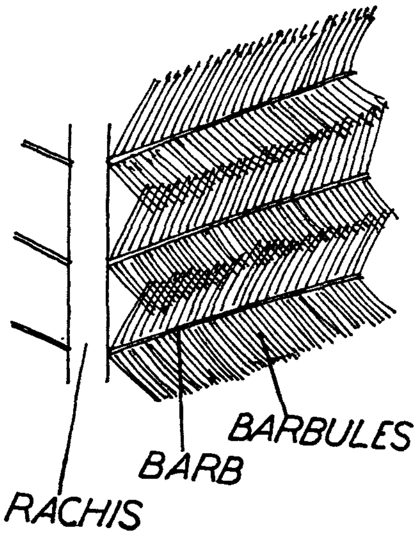


Fig. 39. Diagram of part of a quill feather, showing the interlocking barbules.

The structure of the filoplumes and down feathers is shown in Fig. 40. The filoplume has a very delicate rachis, which is bare except at the tip, where there is a tuft of barbs. The down feather, on the other hand, consists of a tuft of barbs with no rachis.

The flight of a bird is a very complicated movement, and has not yet been fully explained in detail. The downward beat of the wing gives lift by pressing down on the air beneath, maintaining

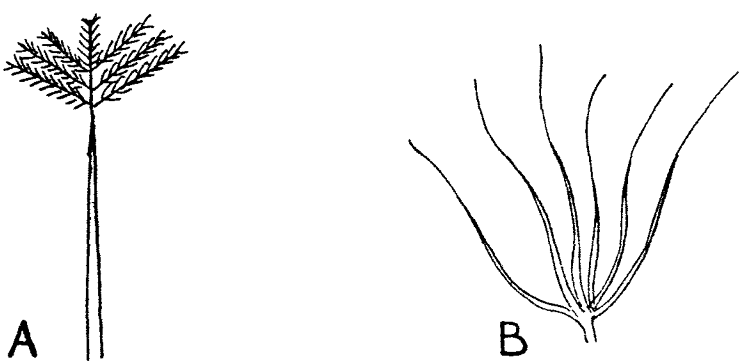


Fig. 40. A, Filoplume and B, Down feather of a bird.

the bird in the air. As the wing beats down the hinder edge lifts somewhat, so that air compressed by the downward beat is swept back and up behind the bird, giving it a forward thrust. In this way, forward movement is maintained, in spite of the fact that actual movement of the *front* edge of the wing is itself slightly forwards. The tip of the wing usually tends to describe a "figure-of-eight" path. The whole question of flight is, however, very complex, and cinematograph films of birds in flight have shown various strange wing movements that are very hard to explain satisfactorily by any theory of flight.

If we compare a bird with an aeroplane, we find that many of the tricks of the aircraft designer have been anticipated by the birds. For example, in many birds the feathers are pulled apart somewhat at the wing tips during flight. This resembles the Handley-Page "slotted wing" device, developed to prevent aircraft from stalling at low speeds. The structure of the bird's wing, with its thick leading edge and thin trailing edge, is also similar to the wing of an aeroplane. Anyone who has watched a seagull in flight will have noticed how the bird tucks its legs away beneath its body, like a retractable undercarriage.

The main movement in flight is imparted by the down beat of the wings, but in some birds in certain circumstances the upward stroke may give a certain amount of propulsive force. In the pigeon, for instance, the up stroke supplies part of the propulsion when the bird is taking off, but when level flight has been attained most or all of the forward movement seems to be the result of the down stroke. During the up stroke, in most birds, the wing feathers move apart somewhat, allowing air to pass through the wing and reducing air resistance to the upward movement. The important of this is obvious.

In addition to flapping flight, most birds can indulge in gliding and soaring. Here the wings are held stiffly extended, the bird relying on air currents to gain height. The seagull is a past master of this kind of flight.

The tail of the bird has important functions during flight. It acts as a rudder, helping to steer the bird to right or left, though steering is also assisted by movements of the head, body and wings—just as a cyclist steers and balances with his body rather than with his hands. When alighting, the tail acts as an air brake, the feathers being extended and whole tail raised. This

can be compared with the action of the "flaps" of an aircraft, which are let down when coming in to land.

Besides the development of feathers and wings, there are various other ways in which the structure of birds is adapted to help them in flying. In order to move the wings, powerful muscles are needed, for the wings have to support the weight of the bird against the resistance of the air. The down-stroke of the wings makes heavy calls on the muscle power of the bird, and so it is not surprising that the breast muscles of a bird are particularly large and well developed.

The vigorous movement of the wings would be impossible without a rigid skeleton to support the muscles of the body. This is especially shown by the highly developed breast bone (sternum) of a bird, with its deep keel. Birds that do not fly are without this keel on the breast bone. They do not need it, for their muscles have less work to do. In the skeleton of a bird, some of the bones are fused together, giving greater rigidity.

Besides being strong and rigid, the skeleton of a bird must be light: it would not help the bird to fly if rigidity were gained at the cost of excessive weight. We therefore find that many of the larger bones are hollow. This makes them light without reducing their strength. We see the same principle in the construction of a bicycle frame, which is made of hollow steel tubes. A steel tube is as rigid, or nearly so, as a solid bar of the same diameter, but it is, of course, much lighter.

Flying is an energetic business, so a bird must have a sufficient supply of energy to keep it going. This comes from respiration—the oxidation of food materials in the cells of the body, with release of energy. Oxygen is taken in by the lungs in breathing, so it is not surprising that birds have a highly efficient lung system.

Although birds have lungs, their breathing system is quite different from ours. In a mammal, the lung has only one outlet—the bronchus, a tube that leads to the "windpipe" (trachea) and thence to the nose and mouth. When the chest expands the lungs expand too: air is drawn into them, and driven out again when the chest and lungs contract. In the lung, the air occupies a complex system of very fine tubes—the bronchioles—that end in little cavities called alveoli. It is in the alveoli that the air gives up its oxygen to the blood, receiving in exchange carbon dioxide, the by-product of respiration.

This system is not as efficient as it could be. When we breathe out, we do not empty our lungs completely: some of the stale air remains in the air spaces, the amount remaining depending on how "deeply" we breathe.

When you take violent exercise, you pant. The movements of your chest increase, the expansion of your lungs as you breathe in is greater, and you take in more air. Even then, however, you are not sweeping all the air out of your lungs when you exhale: there is still some stagnation. This is not entirely a disadvantage, however, as the carbon dioxide left in the lungs acts as a stimulus to keep you breathing.

The lungs of a bird are connected with large air-sacs in the body. When the bird breathes in, air is drawn through the lungs into these air-sacs. On breathing out, air from the air-sacs passes again through the lungs, which do not themselves expand and contract. Blood circulating in the lungs of the bird can take in oxygen and get rid of carbon dioxide when the bird breathes out as well as when it breathes in. Air is drawn right through the lungs in both directions, so that there is no stagnation. This is a much more efficient breathing system than ours.

A bird is like an aeroplane in that it must develop a great deal of power in proportion to its weight: it must have what the engineers call a high power–weight ratio. A land animal is more like a motor car: it only has to move itself along, and does not have to support the whole of its weight by muscular action. It can therefore afford to be heavier for the same amount of power.

The oxygen that helps to give birds their energy is carried round the body by the blood. A great deal of oxygen is needed, so the circulation of the blood must be highly efficient, requiring a well-developed heart. Without this, birds could not fly effectively.

Birds are warm-blooded animals. This means that the temperature of their blood is kept constant, above that of their surroundings: in this way they resemble the mammals and differ from other vertebrate animals. The temperature of birds is, on the whole, rather higher than that of the mammals: if your blood had the same temperature as a bird's, you would be suffering from a severe fever.

The advantage of having warm blood is that you are not at

the mercy of your surroundings. A cold-blooded animal, such as a reptile, cannot remain active when the temperature outside is low for, as its body temperature falls, all its vital processes slow down. Most reptiles therefore have to hibernate during the winter, if they live in a climate such as ours. A warm-blooded animal maintains its body temperature at a constant level by means of its blood, the energy needed to do this coming from respiration. It is just as active in the winter as in the summer. There are a few warm-blooded animals, such as the hedgehog, that hibernate during the winter, but these are relatively few, and their habit of hibernation is probably related to the difficulty of finding food in the winter rather than to inability to maintain the temperature of the body.

A warm-blooded animal must guard against excessive loss of heat to its surroundings. Its body must be "lagged" with something that conducts heat badly, so as to keep the heat in. In the birds, the feathers serve to keep the body warm, for the air trapped between the feathers, being a poor conductor of heat, insulates the body against excessive heat loss.

Apart from the bodily adaptations that enable them to fly, birds are modified in a great variety of ways according to their mode of life, and particularly their feeding habits. This shows itself especially in the form of the beak. Compare, for instance, the hooked beak of a bird of prey, such as the eagle or the hawk, with the beak of the spoonbill which, with its flattened tip, is used for straining food particles from mud. You can tell a lot about the feeding habits of a bird merely by looking at its beak.

We are used to associating birds with flying, but we must not forget that there are many birds that do not fly at all. The ostrich and the penguin (Plate 16) are examples. The penguin is one of the most remarkable of birds, and its successful colonization of the Antarctic is a wonderful instance of adaptation to a very inhospitable environment. In this the penguin has been helped by the way in which its wings have become modified for swimming instead of flying. We are reasonably certain that the ancestors of the penguin were able to fly, though they must have given up doing so a very long time ago. The nearest living relatives of the penguin are the birds of the auk family: the great auk, which has recently become extinct, was very like a penguin, though its home was the Arctic and not the Antarctic.

Although both birds and mammals are warm-blooded, they are probably not directly related to one another. We have good reason to believe that both groups have descended from the reptiles.

Birds resemble reptiles in a number of ways, including the presence of scales on their legs. The earliest known fossil bird, *Archaeopteryx*, was very like a flying reptile. It comes from the Upper Jurassic, and had teeth like those of a reptile and a long, flexible tail.

CHAPTER XVII

THE MAMMALS—CLASS MAMMALIA

We come now to our final class of the Animal Kingdom—the class to which we ourselves belong, together with most of our familiar four-footed animals such as cats, dogs, monkeys, sheep, horses, cattle, rabbits, mice, rats and all the other furry creatures. The mammals also include some animals that, at a casual glance, might not seem to fit quite so well: the whales, the bats and the curious egg-laying duckmole or duck-billed platypus are examples.

Mammals differ in various ways from other animals. The most important difference, from a strictly zoological point of view, is one that may seem trivial: they have a lower jaw of which the skeleton consists of a single bone, the dentary, on either side. To the scientist, this difference is an important one, for it helps us to ferret out the past history of the mammalian line of descent by studying fossils.

A more obvious feature of the mammals, and one that is familiar to everyone, is that they are the only animals to possess true hair. Other animals, such as certain caterpillars, may be loosely described as "hairy," but they do not have hair in the zoological sense. Their "hairs" are really fine bristles: emergences of the skin, without roots. The hair of a mammal is set in a kind of socket in the skin, called a follicle, to one side of which is a gland, the sebaceous gland, which produces fatty material. At the base of the hair is a muscle: when the muscles of the hairs contract, the hairs "stand on end." A mammalian hair is quite a complex structure.

Hair is important to a mammal because it helps to maintain a constant body temperature. Have you ever wondered how your cat can wander about happily in the snow, whereas if you

went out you would need a thick overcoat, and even then you would feel cold? The cat has its own fur overcoat: air is trapped between the hairs, forming a layer of still air all round the cat's body. Air is a very bad conductor of heat, so the cat is beautifully insulated against the cold outside. Later on, the same cat will flop down in front of the fire, and soon the fur on its back will be so hot that you can hardly bear to touch it. All the cat feels, however, is a pleasant sense of gentle warmth: again, it is protected by its overcoat of fur and air.

Mammals, like birds, are warm-blooded, and this has no doubt been a big factor in their success. Their ability to maintain a constant body temperature, irrespective of the temperature of their surroundings, has helped them to spread to all parts of the world, from the Arctic to the Antarctic, and, with some exceptions, it has relieved them of the need to hibernate during the winter.

Another feature of the mammals, and one from which they get their name, is that they suckle their young. With the exception of the Monotremata (see later) the young of mammals are born alive, and during the early part of their life they are fed by their mother on milk, produced by glands, called mammary glands, on her body. The mammary glands are provided with teats through which the young animal can suck the milk: the udder of a cow is an extreme example.

If you dissect the body of a mammal, you will find another feature that belongs to the mammals alone. The thorax or "chest," containing the heart and lungs, is separated from the belly or abdomen, containing the intestines, by a sheet of muscular tissue called the diaphragm. The thorax of a mammal is a closed box. This, and the presence of the muscular diaphragm, has an important bearing on the mammalian method of breathing.

The diaphragm, when at rest, is convex, arching forwards into the chest cavity. When a mammal breathes in, the muscles of the diaphragm contract, so that it flattens, thus enlarging the chest cavity: the process is augmented by the movements of the ribs. The lungs expand, and air is sucked in. On breathing out, the reverse process takes place. You may, at some time or another, have had the unpleasant experience of being "winded' while playing rugger. This means that a blow below the diaphragm has affected the nerves supplying it, and thus temporarily paralysed

its muscles, so that you cannot breathe. The action of breathing is partly controlled by a group of nerves called the solar plexus, just below the diaphragm—as every boxer knows.

The most primitive of the mammals living today are the Prototheria or Monothremata, of which only two genera are known, both from Australia. These are the duck-billed platypus or duck-mole (*Ornithorhynchus*) and the spiny ant-eater (*Echidna*). We know little of the past history of these two very interesting animals, but it seems certain that they are remnants of a very ancient stock, probably going back for 100 million years or so.

The monotremes are the only mammals to lay eggs instead of bearing their young alive. In this respect they resemble the reptiles, but they possess mammary glands that provide milk for the young, though the passages or ducts from the glands are not formed into nipples that the young can suck. In these animals the capacity to feed the young on milk is still in its most primitive form.

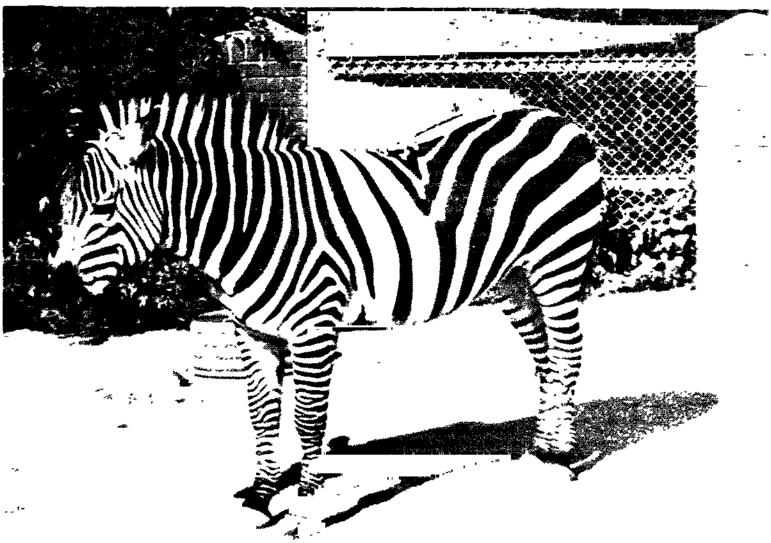
The duck-billed platypus is a curious animal, with very broad webbed feet and a flat tail. Its most striking feature, however, is its large flat beak, shaped like the beak of a duck. It has no teeth. It is mainly aquatic, burrowing by the side of water.

The spiny ant-eater is rather like a porcupine to look at. There are several species, found in Australia and New Guinea. Their bodies are specialized for catching and eating ants, with very long snouts and tongues: in this respect they resemble the great ant-eater (*Myrmecophaga*) of South America, though there is no actual relationship at all.

The monotremes are in many ways intermediate between reptiles and mammals. They lay eggs, and, though they are warm-blooded, their temperature varies: they have not the delicate temperature control of the more advanced mammals. On the other hand, they have the typical single lower jaw bone of the mammals, they have hair, and they suckle their young after a fashion.

Another primitive group of mammals is the sub-class Metatheria or Marsupialia, in which, though the young are born alive, they are not fully developed at birth, and are carried by the mother in a special pouch (marsupium) on her body until development is complete.

The marsupials are mainly found in Australasia, but there are



19. Skull of the tiger. Note the large canine teeth and the flat, pointed premolars and molars that work beside each other with a shearing action.

20. The sea-lion (Chessington Zoo, Surrey). This is a carnivore specialized for life in water.

21. The zebra, a near relative of the horse (Chessington Zoo, Surrey).

22. THE BARKING DEER (*Muntiacus muntjak*), FROM SOUTH-EAST ASIA (CHESSINGTON ZOO, SURREY).

23. SKULL OF A PIG. NOTE THE "GENERAL PURPOSE" TYPE OF TEETH, SUITABLE FOR AN OMNIVOROUS DIET.

24. SKULL OF THE SHEEP. THE TEETH ARE ADAPTED FOR A HERBIVOROUS DIET.

a few American species, such as the opossum. The most familiar of all the marsupials is the kangaroo.

The opossums are found over a considerable area of the American continent, from South America through Central America and extending into the southern part of the United States. They are tree-living creatures, able to grip branches with their tails, and they live mainly on insects.

Some of the Australasian marsupials show interesting resemblances to the more advanced mammals (Eutheria). There are no Eutheria native to the Australian continent, but they are replaced by marsupials of a similar kind. Thus we have the Tasmanian wolf—now probably extinct or nearly so—which is very like a wolf to look at, the marsupial cat (*Dasyurus*), the marsupial mouse (*Sminthopsis*), the marsupial mole (*Notoryctes*) and so on.

A very attractive little marsupial, which has become well known since its television appearances, is the koala bear (*Phascolarctos*). This tree-living marsupial looks like the teddy bear of the toy shops. Another curious marsupial is the wombat (*Phascolomis*). This is a fairly large animal, with no tail, which burrows in the ground and eats roots.

Fossil remains of marsupials are found all over the world, showing that they once had a world-wide distribution. Today, they are much more restricted. Modern mammals (Eutheria) are not native in Australia, though some, like the rabbit, have been imported. This can probably be taken to mean that the Australian continent was separated from the rest of the world by the ocean before any of the modern mammals had succeeded in getting there. Isolated in this way, the Australian marsupials have been able to thrive without competition from the modern mammals, while in the rest of the world the Eutheria have gradually ousted them, owing to their superior bodily organization, and perhaps also to their greater powers of adapting themselves to widely differing conditions.

The third great group of mammals, and by far the largest, is the Eutheria, also known as the placentals. This is the group that contains all the familiar mammals, and a great many more that are less familiar.

The placentals get their name from the placenta, which is a structure formed in the uterus (womb) while the embryo young are developing there, and to which the embryo is attached, before

birth. The placenta is richly supplied with blood vessels, and the blood supply of the mother is thus brought very close to the blood system of the embryo, though the two blood streams do not actually mingle. Food materials and other things can, however, diffuse from the blood of the mother to that of the embryo.

In the marsupials there is no placenta, and the connexion between the mother and the unborn young is much more casual. The arrangement for the care of the young before birth—and in many cases after it—reaches a higher level of development in the placental mammals than in any other group of animals. This has probably had a great deal to do with their success.

The young of the placentals are born fully developed, though they are often helpless for a time. They are fed on milk by the mother until they can feed themselves, and in most of the placentals the amount of after care given to the young by the mother is considerable.

The placental mammals form a very large group, and a very diverse one. Most of them are terrestrial animals, but aquatic forms are well represented, and in some, such as the whales, the bodily adaptation to life in water is so great that one might be excused for thinking, at first sight, that they were fishes. In the bats, we have mammals that are adapted for life in the air. In this short chapter I can do no more than indicate, very briefly, some of the more important lines along which the mammals have developed.

The order Insectivora contains a number of interesting insect-eating animals, the most familiar to us being the hedgehog (*Erinaceus europaeus*) and the common mole (*Talpa europaea*). The hedgehog is one of the few wild mammals that may be found in suburban gardens, and it is on the whole a friend of the gardener, since it includes in its diet insects and slugs, as well as small birds. It will also eat snakes. It is sometimes said that the hedgehog is not harmed by the poison of the adder, but, as Maxwell Knight points out in his excellent book (see List of Recommended Books), it is more likely that the hedgehog escapes harm by its skill and quickness in rolling itself into a prickly ball, and so protecting its head and soft parts from the bite of the snake.

The moles are mammals that are highly specialized for life underground. Their fore-limbs, which are very strong, are like paddles, for digging. Their eyes are small, and may possibly be

functionless, they have very small flaps (pinnae) to their ears, and their fur does not lie in any particular direction along their bodies, and so cannot be ruffled by passage through the soil.

The shrews are small insectivores, something like long-nosed mice. The pigmy shrew (*Sorex minutus*), a British species, is one of the smallest of all the mammals.

The order Cheiroptera includes the bats, the only mammals that can really fly. The wings of the bat are folds of skin that stretch from the second finger of the hand to the tail: they are supported by a framework made up from the bones of the hand, the forearm and the hind leg. The breastbone of the bat has a keel, like that of a bird, which serves for the attachment of the powerful breast muscles needed to work the wings.

Bats are nocturnal animals, and they are remarkable for the way in which they can avoid obstacles when flying, even in the dark. This they do by a kind of radar mechanism: as they fly they are constantly squeaking, and the acute sense of hearing provided by their very large ears enables them to pick up the echo of their squeak as it is reflected from an obstacle, and so take evasive action. Their method of navigation might be compared with the "asdic" apparatus used during World War II for detecting submarines under water. The squeak of a bat is of such a high pitch that many people cannot hear it at all.

Our British bats, of which there are twelve species, feed on insects, which they catch on the wing. The blood-sucking vampire bats (Phyllostomatidae) are found only in Central and South America. The largest of the bats are the fruit bats or "flying foxes" (Megacheiroptera) of Asia, Africa and Australasia: some of these are five feet across the wings.

The order Edentata contains some interesting animals, many of which are insectivorous. The name Edentata means "without teeth," and in a number of edentates the teeth have disappeared altogether, no doubt as a result of eating soft food such as insects and other invertebrates. Other Edentata have teeth of a rather simple kind.

The armadilloes are some of the most curious of the edentates. In form they recall the turtles: their bodies are protected by bony plates in the skin, the plates being themselves covered by horny structures called scutes. The teeth are very simple in structure, and more numerous than in most mammals. The armadillo is a

native of South America, one species extending through Central America into the southern United States. The armadilloes feed on insects, dead animals and other things.

Among other members of the Edentata, the ant-eaters are outstanding. The largest of these is the great ant-eater (*Myrmecophaga*), whose home is in South America. This animal may reach a length of more than six feet. It has long hair and a bushy tail, but its most striking feature is its very long snout. Its tongue is also very long, and is used for catching ants.

The sloths are an interesting group of edentates, adapted for life in trees. They are found in Central and South America. They hang upside down from branches, moving very slowly and eating leaves as they go.

The order Primates is one of particular interest to us, for it includes both the monkeys and ourselves. The Primates as a whole show certain resemblances to the Insectivora, and may well have come originally from insect-eating animals living in trees. One of their important characteristics is that the thumb is opposable—it can be bent round to meet the other fingers. In many of the monkeys this is also true of the big toe. An opposable thumb or big toe enables its owner to grasp things, which is useful in a climbing animal.

Another primate feature is the way in which the eyes have come to be placed in the front of the head, looking straight forwards. This gives binocular vision: an object is seen by both eyes at the same time. Besides giving clarity of vision, the slightly different viewpoint of the two eyes makes it possible to judge distances accurately.

A third, and very important, character of the Primates is the size of the brain. Not only is it large: the cerebral hemispheres, which form the "thinking" part of the brain, are especially big and complicated. This is particularly so in man.

We can divide the Primates into two sub-orders: the Prosimii and the Anthropoidea. The Prosimii include the more ancient monkeys, such as the lemurs of Madagascar—bushy-tailed, tree-living monkeys, rather like squirrels. They also include the bush-baby (*Galago*), now well known on account of its appearances on the television screen, and the strange little tarsiers, with their enormous eyes adapted for vision at night, and adhesive pads on the ends of their fingers.

The Anthropoidea are often divided into two groups: the Platyrrhina or New World monkeys, and the Catarrhina containing the Old World monkeys and man.

The New World monkeys are found only in South America. The best known of them is the marmoset (*Callithrix*). This attractive little animal lives on insects and fruit in the tropical forests of South America. It has a bushy tail like a squirrel, and claws on its fingers and toes that enable it to run up tree trunks.

The Old World monkeys come from Asia and Africa. They include, amongst others, the baboons (*Papio*), the mandrills (*Mandrillus*), and the great apes (*Pongidae*), such as the orang-utan (*Pongo*), the chimpanzee (*Pan*) and the gorilla. Man (*Homo sapiens*) is also included here.

We come now to a large and important order called the Rodentia. These are gnawing animals, and among them we find the rats, mice, voles, squirrels, guinea-pigs and many others. The rabbits and hares used also to be included in the Rodentia, but they are now placed in an order of their own, the Lagomorpha.

The rodents are all small animals, and they breed very quickly, so that they are often found in enormous numbers. They are especially remarkable for the way in which their teeth have become adapted for gnawing. Their incisor ("front") teeth are reduced to a single pair in each jaw, and are sharp and chisel-like. They continue to grow throughout the life of the animal, so that they are renewed as fast as they are worn away by use. There are no canines ("eye-teeth"), and the pre-molars and molars ("back teeth") are flat-topped and suitable for use as millstones for grinding. Between the incisors and the first of the pre-molars there is a long toothless gap called the diastema.

The rats (*Rattus*) are among the most successful of the rodents, and are a serious economic problem at the present time, as they spoil food and other materials and carry disease. There are two species: the brown rat, which is the larger of the two, and the more active black or Oriental rat. The black rat is the one commonly found in shipping: it is a good climber, and has recently become more common in the City of London, possibly owing to the greater care now taken in making basements rat-proof. This is fairly effective against the brown rat, but it does not stop the black rat, which is just as likely to get in through the roof.

The black rat is particularly important because one of its fleas, *Xenopsylla cheopsis*, is the carrier of bubonic plague.

The common mouse (*Mus musculus*) is even more numerous than the rat. It has spread to all parts of the world, and it appears even to have reached the continent of Australia before man got there. Both the rat and the mouse can be regarded, in a sense, as parasites on man, for they live mainly in the neighbourhood of human habitations and consume food intended for man.

The voles are related to the rats and mice, which they resemble in appearance. The so-called "water rat" is really a water vole. The voles often have longer tails, relative to the length of their bodies, than the rats and mice, but the commonest of all, the field vole (*Microtus agrestis*), has a short tail.

The dormouse (*Muscardinus avellanarius*) lives in trees, especially hazel (*Corylus avellana*). If you know your "Alice" you may remember that, at the Mad Hatter's tea party, the dormouse disgraced itself by going to sleep. The dormouse is, in fact, remarkable for the length of time for which it hibernates, and for being difficult to rouse when it is hibernating.

The squirrels are among our most attractive wild mammals, though they do a lot of damage to woodlands. Our native one is the red squirrel (*Sciurus vulgaris*), which mainly inhabits pinewoods. It is being ousted by the imported grey squirrel (*S. carolinensis*), which is at home in woodlands of almost any kind.

Among exotic rodents, two stand out in the minds of most people: the porcupine (*Hystrix*) and the beaver (*Castor fiber*). It is not true that the porcupine can shoot its quills at approaching enemies. Beavers (Plate 18) are aquatic rodents, and they are well known for the impressive dams they build across rivers in summer, apparently with the object of making the water deeper. Beavers build themselves houses or "lodges" at the sides of streams. These are dome-shaped, and constructed of sticks and mud. In the winter the wall and roof of the lodge freeze hard, serving the double purpose of keeping the beavers warm and protecting them from bears, wolves and other enemies.

The rabbits and hares are nowadays placed in the order Lagomorpha. We have only two native members of the order: the brown hare (*Lepus europaeus*) and the mountain hare (*L. timidus*). The rabbit (*Oryctolagus cuniculus*) is not really native to Britain: it was introduced into this country by man, probably

during Norman times, and has spread rapidly. In much more recent times it was introduced into Australia, with disastrous results, for it has spread so quickly that it is now a major pest.

Hares are larger than rabbits, with longer legs. They live by themselves, and do not burrow. During the mating season, in early spring, the males go through a conspicuous period of courtship—hence the expression "mad as a March hare."

Rabbits are highly gregarious animals—i.e., they flock together in large numbers. They live in underground warrens, and cause immense devastation to the country immediately surrounding the warren—or did before myxomatosis cut down their numbers. Myxomatosis is an infectious disease of rabbits that threatened at one time to exterminate them.

The order Cetacea contains the whales, porpoises and dolphins —some of the most remarkable of the mammals. They are entirely aquatic, and in their return to the water as a home they have taken on many of the external characters of the fishes, such as the streamlined shape, presence of fins and absence of neck. They are, however, still mammals. Their young are born alive and are suckled by the mother; they are warm-blooded; they breathe air by means of lungs though, by virtue of their wonderful system of oxygen storage, many whales can stay submerged for more than half an hour before coming to the surface to breathe. An important mammalian character that they lack is hair—though some whales have sensory bristles in the neighbourhood of their mouths.

The whales vary a great deal in their nutrition. The killer whale (*Orca gladiator*) is carnivorous. It is a savage beast, showing considerable cunning in stalking its prey, and is able to kill and eat almost any animal afloat, including other whales. The sperm whales (Physetoroidea) have a great reservoir of sperm oil in their enormous, blunt snouts: they feed mainly on cephalopod crustaceans. The whalebone whales are filter feeders, straining plankton from the sea water by means of great strainers made of plates of whalebone (a kind of horn). One of these is the blue whale (*Balaenoptera musculus*). This great creature, often a hundred feet long and weighing 150 tons, has the distinction of being the largest animal alive today, and its great size is a tribute to the efficiency of filter feeding.

The order Carnivora includes the flesh-eating mammals such

as the cats, including the great cats like the lion and tiger, the dogs, the wolves, the bears and a host of others. It also includes the sea-lions, seals and walruses.

The cats show adaptation to the carnivorous habit more strongly than other sections of the order: they are also among the most beautiful and perfectly adapted creatures that Nature has ever produced. The domestic cat (*Felis domestica*), which has been justly called a "pint-sized tiger," shows the characters of the Felidae very well. Notice first the teeth (Plate 19). The incisors are small, and used mainly for cleaning the coat. The canines are large, curved and pointed: they are weapons both of offence and defence, and are also used for holding prey. The cheek teeth (pre-molars and molars) are large and flattened in a fore-and-aft direction, with pointed tops: the top and bottom teeth work with a shearing action, like the blades of a pair of scissors, and are ideal for tearing flesh.

The feet of a cat are armed with formidable claws, used both in fighting and in capturing prey. The claws can be retracted into the soft pads on the toes, so that the footfall of a cat is as soft as a snowflake, enabling it to creep up on its prey without being heard. Cats do not chase their prey: they stalk it, until they get within leaping distance.

The eyes of a cat both look forwards, giving it the advantage of binocular vision (see page 132). It can judge distances with great accuracy. Watch a cat leap up on to a table. It calculates its jump to a nicety: just far enough, and not a millimetre too far. Besides its capacity for judging distances, it has supreme muscular control. Both these characteristics are vital to it when, having stalked its prey, the moment comes for the final leap that will carry it squarely on to the back of its unsuspecting victim. The cat tribe are the supreme carnivores.

The domestic cat can hardly be called a wild animal, for it has lived with man since the days of the Pharaohs, and possibly before. We have, however, a wild cat, *Felis silvestris*, still living in the Highlands of Scotland, though its numbers are getting less.

The lion (*Felis leo*) is found in Africa and Asia, usually in open country rather than in forest. The lion differs temperamentally from the other big cats: it responds well to domestication and makes an excellent pet—though rather robust when fully grown. The tiger (F. *tigris*) is found only in Asia, where it has a very

wide distribution, ranging as far north as Sibera. Unlike the lion, the tiger is a solitary animal, living and hunting alone. When in captivity the tiger can be crossed with the lion, the resulting hybrid being known as a tigon. The leopard (*F. pardus*) occurs in both Asia and Africa: though smaller than the lion and tiger it is still a formidable animal, often growing to a length of five feet. The jaguar (*F. onca*) and the puma (*F. cougar*) both come from the American continent.

The dogs (Canidae) are somewhat less specialized carnivores than the cats. The domestic dog (*Canis familiaris*) has lived with man since prehistoric times, and its origin is unknown. The wolf (*Canis lupus*) is world-wide in its distribution, though absent from one or two places, such as New Zealand. It was abundant in Britain up to and including the Middle Ages, but has since become extinct, though it lingered on in Scotland until the eighteenth century. The fox (*Vulpes vulpes*) is still common over most of Britain, but it would probably be rare if it were not protected for hunting.

The bears (Ursidae) appear to be related to the dogs rather than the cats. They have a very wide distribution. Some, such as the polar bear, are extremely savage, while others have learned to tolerate man, though they have not become as friendly as the dog. Motorists in the Smoky Mountains of Tennessee and North Carolina who leave a car door open while they get out to admire the view will sometimes return to find one of the small black bears of the district sitting in the driving seat, probably rummaging through the picnic hamper. In such circumstances the only course of action is to watch the bear eat the family lunch, and resume the journey when, replete, he has decided that he no longer needs the car. These bears have become adept at robbing the wayside litter bins, where they find scraps of food, and they do not appear to be in the least put out by the presence of an admiring crowd of motorists.

The Mustelidae are a family of carnivores with a number of British representatives. These include the stoat (*Mustela erminea*), the weasel (*M. nivalis*), the polecat (*M. putorius*), the badger (*Meles meles*) and the marten (*Martes martes*). The otter (*Lutra lutra*), an aquatic carnivore, is also included here.

The seals, sea-lions (Plate 20) and walruses (sub-order Pinnepedia) have become adapted for a completely aquatic life, though

they still come ashore to breed. The sea-lions are rather more agile ashore than the seals, as they are able to turn their legs forward for movement on land.

The order Proboscidea includes the elephants, of which there are two genera alive today: the Indian elephant (*Elephas*) and the African elephant (*Loxodonta*). The mammoth (*Mammuthus*) has been extinct for some thousands of years.

The most notable features of the elephants, apart from their great size, are the great elongation of the nose to form the trunk, used for gathering food, and the tusks, which are the upper incisor teeth. Elephants are active animals, in spite of their size, and a great deal of energy is needed to power their great muscles. This means that a lot of food must be eaten: an elephant needs to feed for something like eighteen hours out of twenty-four if it is to keep itself going. In captivity, of course, a great deal less muscular energy is expended and less food is needed.

The order Perissodactyla is a small one, but important because it contains the horse. It also includes the rhinoceros and the tapir.

In the horses (*Equus*) the legs are adapted for fast running. This has brought the heel well off the ground, and the sole of the foot as well: the animals walk, not merely on tiptoe, but actually on their finger-nails and toe-nails (the hooves). The number of digits is reduced: in the horses, only the middle finger and middle toe remain.

The horse, the ass and the zebra all belong to the genus *Equus*. The domestic horse (*E. caballus*) is not found wild, but species of wild horse, as well as wild asses, exist in various parts of the world. There are also several species of zebra (Plate 21), all African.

Our final order is the Artiodactyla, also consisting of hoofed mammals. Here we have the cow, the sheep, the pig and the goat, as well as the various kinds of deer (Plate 22), the antelopes, the giraffe, the llama, the hippopotamus, the camel and many other creatures less familiar.

In the Artiodactyla, as in the Perissodactyla, the number of digits is generally reduced, but in the Artiodactyla the number of toes is even, whereas in the Perissodactyla it is odd. The most specialized of the Artiodactyla retain the third and fourth digits: we see this, for instance, in the camel. In deer and cattle, the second and fifth digits are present, but are reduced in size to

varying extents in the different species. The first digit (thumb or big toe) has been lost in all living Artiodactyla.

Another feature shown by many of the Artiodactyla is the great complexity of the stomach. This is found in those species that chew the cud—i.e., regurgitate their food, after it has been swallowed once, for further chewing. Next time you see a herd of cows, see how their jaws move, even though they are not cropping grass, as if they were chewing-gum addicts. The stomach of a cow or a sheep is divided into four sections, the food passing from one to another. This complexity of the digestive system is no doubt connected with a diet of herbage, which needs a great deal of chewing and is hard to digest.

We have now completed our brief survey of the Animal Kingdom. The number of different kinds of animals is so large that much has had to be left out, and to make good these deficiencies I must refer you to the "List of Recommended Books," which you will find on page 140. Most of them are easily obtainable from libraries.

Before I finish, I would just like to repeat one thing that I said in the first chapter. Zoology is the study of animals, and animals are alive. If you want to get to know them, you must study them alive as far as possible. Go out into the field and look for some of our native animals, large and small, vertebrate and invertebrate. There are lots of them about, if you take the trouble to look, but you will have to go quietly and have patience to wait and watch. If you can persuade someone to give you a pair of binoculars, you will find them worth their weight in gold. A camera, too, is a useful thing to have: photographing wild life is great fun, though it is not easy. But, whatever else you do, go out and look.

LIST OF RECOMMENDED BOOKS FOR FURTHER READING

BARRETT, J., and YONGE, C. M. *Pocket Guide to the Sea Shore.* (Collins.)

CARTHY, J. D. *Animal Navigation.* (Allen and Unwin.)

DOWDESWELL, W. H. *Animal Ecology.* (Methuen.)

EALES, N. B. *The Littoral Fauna of Great Britain.* (Cambridge University Press.)

FORD, E. B. *Butterflies.* (Collins.)

IMMS, A. D. *Insect Natural History.* (Collins.)

KNIGHT, M. *Instructions to Young Naturalists. I. British Reptiles, Amphibia and Pond Dwellers.* (Museum Press.)

MACDONALD, J. D. *Instructions to Young Ornithologists: Bird Biology.* (Museum Press.)

MELLANBY, H. *Animal Life in Fresh Water.* (Methuen.)

NEWMAN, L. H. *Instructions to Young Naturalists. II. Insects.* (Museum Press.)

VESEY-FITZGERALD, B. *Instructions to Young Naturalists. III. Mammals.* (Museum Press.)

YAPP, W. B. *Borradaile's Manual of Elementary Zoology.* (Oxford University Press.)

YONGE, C. M. *The Sea Shore.* (Collins.)

YOUNG, J. Z. *The Life of Vertebrates.* (Oxford University Press.)

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